RIVERS OF THE BENGAL DELTA

Calcutta University Readership Lectures

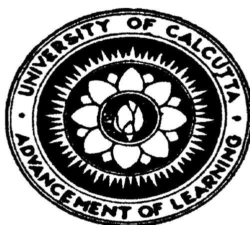
RIVERS OF THE BENGAL DELTA



BY

S. C. MAJUMDAR, C.I.E., I.S.E., M.I.E. (IND.)

CHIEF ENGINEER, BENGAL



UNIVERSITY OF CALCUTTA

1942

PRINTED IN INDIA

PRINTED BY BHUPENDRALAL BANERJEE
CALCUTTA UNIVERSITY PRESS, 48, HAZRA ROAD, BALLYGUNGE, CALCUTTA

1335B—November, 1942—E

CONTENTS

Introduction

I am grateful to the authorities of the Calcutta University for the invitation to deliver a course of lectures on " Rivers of the Bengal Delta." In any country rivers play an important part in the health and economic well-being of the people. They are of vital importance in a deltaic country which the rivers have created. Specially in Bengal, of which the major portion is deltaic, having regard to the seriousness and complexities of the river problems which, as I shall try to explain in the course of my lectures, have arisen partly due to changes in the course of some of the major rivers and partly due to human interference with the natural process in the building up of the delta, river conservancy should be given the first place in any programme of Rural Development. It is my considered opinion that unless these problems can be satisfactorily solved—I shall try to indicate the broad lines of solutions in the course of my lectures—large tracts, specially in the Western, Central and Northern Bengal, where they are already rather acute, will cease to be habitable in the not very remote future. I am not alone in holding this view as the Irrigation Department Committee consisting of independent experts from other Provinces, which was appointed by the Bengal Government in 1930 to consider the question of re-organization of the Department, also recorded similar opinion and stated that these areas will probably " revert to swamps and

jungles" from which they were originally reclaimed by the rivers. It, therefore, behoves every one of us to think about these river problems and their solutions, so vitally affecting the very existence of a large tract of Bengal as a fit place for human habitation and try to educate public opinion as without the co-operation of the public, it is not possible to proceed very far. For this purpose, I could think of no better audience than what I have to-day, as you, who represent the intelligentsia of Bengal, can be expected to take a long view of the future good of the country instead of merely the immediate present, and can, I hope, help in creating an enlightened public opinion in favour of our proposals even though some of them are found to affect adversely some of the vested interests for the time being.

2. Having regard to the object which I have in view, I do not propose to deal with the historical aspect of these rivers nor with their description, except so far as it may be necessary to explain the river problems that have arisen. I would rather utilise the time at my disposal in explaining these problems and indicating, in broad outlines, their solutions. In the first and second lectures I propose to deal with the Inter-Provincial aspects of these problems—how they affect the river conservancy in general with special reference to Bengal conditions and how they can only be tackled by an Inter-Provincial organization. In the third, fourth, fifth and sixth lectures I propose to deal with the rivers in Bengal—the services which they have rendered and which in natural economy they should continue to render, *viz.*, creating the land, draining and fertilizing it and transporting the country's produce, the

obstacles in the continuance of these services and how they could be removed. This portion of my lecture is naturally based on my paper "River-Problems in Bengal" which I read at the Jubilee Session of the Indian Science Congress, but amplified and amended in the light of experience gained and further information that I could collect since then.

Inter-Provincial Aspect of the River Problems

How rivers are maintained in nature.

3. I propose to speak to you this evening on the river conservancy in general, specially emphasizing the inter-provincial aspect of the problem—how rivers maintain themselves in nature and how human interferences in their domain are creating problems which are adversely affecting the services rendered by them and which have to be solved if they are to continue to serve the needs of man. Rivers are sustained by rainfall within their catchment basins. The distribution of rainfall during the year is not however uniform. Specially, in the tropical countries not only most of the precipitation occurs during the three or four monsoon months but even during this period its distribution is erratic, heavy downpour often following days of dry weather; while during the rest of the year very little rainfall can normally be expected. It will, therefore, be seen that if all the precipitation were to flow as surface run-off, we would have disastrous floods following heavy rainfall and no flow during the dry season to sustain animal and plant life. Here nature comes to the rescue and by absorbing and storing

in the subsoil a considerable portion of the precipitation to be released gradually by percolation throughout the year, she compensates for the erratic distribution of rainfall and not only reduces the intensity of floods but maintains the dry weather flow so necessary to serve the needs of man. The extent of this compensating action depends on the nature and condition of the catchment. In flat catchment like Bengal by far the major portion of the precipitation is absorbed and stored by the subsoil ; while in steep hilly catchment, which contributes the major portion of the river flow as the rainfall is much heavier there, the surface run-off would have been much more and the subsoil storage less but for another compensating action provided by nature. If left to nature the hilly catchment usually remains covered with thick growth of vegetation which retards run-off, thus reducing the intensity of floods, and increases the subsoil storage giving us more dry weather flow. As the capacity of a river to serve the needs of man depends not so much on the monsoon flow, which often causes destructive floods, but rather on the flow which it can maintain throughout the year, it is this invisible percolation flow from subsoil storage all over the catchment basin, specially the hilly catchment, which is really the more important factor and must not be allowed to diminish if the river has to continue to render such services efficiently.

Extensive deforestation aggravating the floods and reducing dry weather flow.

4. Owing to the pressure of population and to serve the needs of advancing civilization this natural condition, however, can no longer be maintained. Extensive deforestation is going on ; more and more of the river domains are being

gradually encroached upon. Larger and larger areas are being opened up to find room for the growing population and cultivation; extensive forest-clad hill slopes are being laid bare rapidly and often indiscriminately to meet the needs of modern civilization; and even the undergrowth is being destroyed due to excessive grazing by the growing cattle population. As a consequence more and more of the precipitation is now flowing as surface run-off into these rivers thus increasing the intensity of floods and reducing the subsoil storage, which in its turn is reducing the dry weather flow so necessary to serve the needs of man—for irrigation, navigation, domestic supply, etc.

Reduction in dry weather flow responsible for deterioration of tidal channels and increased salinity in tidal areas.

5. Specially, in the deltaic area like Bengal this reduction in the dry weather flow is a matter of serious concern, as, apart from its adverse effect on navigation, it is causing rapid deterioration of the tidal channels. It may be mentioned here that tides in Bengal carry a large quantity of silt. Source of this silt is no doubt what has been carried by the upland flood carriers from their catchment basins; a portion is deposited on their spill areas, where available, which are being gradually raised; a portion gets consolidated at their mouths which gradually extends the delta; and the rest remains in an unconsolidated state and is dispersed by the strong tidal current along the delta face. Tides while travelling up the large number of tidal channels pick up this silt almost to the saturation point, *i.e.*, to the extent that the tidal velocity during flow tide, which is usually very high, can transport. Indeed in addition to the upland flood-carriers Nature is also employing this tidal agency for

the purpose of raising the lower portion of the delta where spill areas are available for free spill. While this beneficial act of raising of the land by silt deposit is proceeding, the silt-free water flowing back to the channels during ebb tide, by scouring the silt deposited in their beds during flow tide, is maintaining them in efficient condition. In the case of most of the tidal channels in Bengal, however, the spill area has either been raised sufficiently high and spilling is no longer possible or, as is generally the case, owing to pressure of population, it has been prematurely reclaimed by means of marginal embankments and is no longer available for spill. In consequence the silt, which in the economy of nature should have raised the low land, is being deposited in the bed of these channels which are in consequence deteriorating rapidly, affecting seriously the drainage and navigation. Drainage of local rainfall no doubt helps to a certain extent in scouring out the silt deposited in these channels but as this is available only during the monsoon months, copious supply of dry weather flow is essential for the preservation of these tidal channels on which depend the health and prosperity of large areas of deltaic Bengal. Another serious consequence of the reduction of the dry weather flow is that the salt water limit is extending further and further up the delta.

Distribution of silt in nature.

6. To revert to the question as to how the rivers maintain themselves it is necessary to refer to the all important factor, *viz.*, the silt which gives rise to most of our river problems. Even if left to nature, rivers must carry certain portion of silt during floods, being picked up along with the surface run-off from their catchment basins.

Indeed, in the economy of nature it is necessary, as without this silt neither could the delta be formed and raised, nor the land fertilized by natural manure. If left to nature, rivers coming down the hill slopes and flowing through non-deltaic region have usually got sufficient gradient and velocity to be able to transport the normal silt-charge; while flowing through the deltaic region with flatter gradient and velocity usually not sufficient to carry the silt burden, it is necessary in the economy of nature that the rivers should spill over their banks during floods and after depositing the silt thereon, the silt-free spilled water should flow down these channels during the subsiding stages of the floods and maintain them in efficient condition. Spill area no doubt rises gradually but along with it the river bed and the flood level also rise and the relative position is not materially altered except at long intervals—perhaps centuries—when the river unable to spill, bursts through the high banks and diverts her course to perform similar delta building function in the adjacent lower areas and so on.

Extensive deforestation increasing the silt charge and deteriorating the rivers, thus arising the flood level and affecting navigation owing to the formation of shoals and reduction in dry weather flow.

7. As a result of extensive deforestation and other factors causing intensive soil denudation in their catchment basins referred to above the silt charge of most of the rivers is however rapidly on the increase. Even in non-deltaic region many of the rivers are unable to carry their increased silt burden which is choking their beds and raising their flood levels. In the deltaic region, navigation, even in the Ganges and the Jamuna, is becoming more and more difficult owing to the formation of extensive shoals. The spill channels are rapidly deteriorating—many of

them having their connection with the parent stream severed soon after the flood season owing to the formation of high shoals at their off-takes, and are thus being deprived of the dry weather flow with serious consequence to the countryside which they traverse.

Excessive deforestation and soil denudation are really world problems.

8. The problems I have discussed above are not confined to India but they are really world problems and in view of their seriousness I quote the following from Lord Hailey's Survey of Africa (An African Survey, by Lord Hailey, Oxford University Press, 1938) :—

" Surface run-off increases where vegetable cover is reduced, since obstacles no longer impede the flow of water, and the soil is no longer kept open and porous by the roots of trees and plants. By far the most efficient type of vegetable cover is deep-rooted natural forest, where run-off is often negligible. Grass, while less efficient than forest, is still much less wasteful than the majority of annual crops, for the run-off may be considerable when the land is left bare and trampled after harvest. Unless preventive measures are taken, a higher rate of surface run-off normally accompanies an increase in cultivation, and there can be no doubt that in Africa a bigger proportion of the rainfall is reaching the sea unutilized than was the case a century ago. To this extent, therefore, the severity of the droughts from which Africa so often suffers has been increased by man

" Springs and wells are fed by reserves of water stored in the subsoil or rock underground. If these reserves dwindle, then wells dry up, springs are reduced to a trickle, and rivers that once flowed strongly all the year round fail altogether

during dry periods and run only during and immediately after periods of rain. The more water lost as run-off, the less is available for underground storage : one of the most serious effects of increased surface run-off, therefore, is a fall in the level of the ground water-table. Such falls have been observed, and to some extent measured, in many parts of the United States ; in Africa the same phenomena of falling water-tables and dwindling rivers exist, although accurate measurements appear to be lacking. Examples of rivers which flowed all the year round twenty or thirty, or even ten years ago, and now consist of a chain of waterholes in dry weather and a muddy torrent in wet, have been quoted from almost all African territories. Apart from the Saharan examples, the cause of which is a subject of some contention, there are many others. Dr. Robert Laws has listed twenty large streams that have ceased to flow in the Mombera district of Nyasaland since he first took up his residence there, nearly fifty years ago. The level of lakes in Uganda is steadily falling, especially Lakes George, Edward, and Kioga, and in Kenya many once perennial streams have now become seasonal.

" A corollary to the dwindling of rivers and streams during dry seasons is the increase of flooding in wet seasons. Storm waters, no longer checked by forest and bush, flow down gullies and hill-sides into the river-beds ; and streams, suddenly swollen, become converted from feeble trickles into rushing torrents heavily charged with silt. It is now an accepted thesis that such flooding is greatly augmented and in some cases caused by deforestation of the watershed. In

France, for example, the correlation between floods and deforestation has been demonstrated in the Savoy region. Between 1738 and 1912, 21 per cent of the forests of this region were destroyed; and whereas during the eighteenth century only eight floods occurred in the area affected, in the nineteenth century the number of floods rose to thirty-eight. It is at the time of such flooding that irreparable damage is done by the removal of soil in the form of silt. Evidence from many parts of Africa points to the fact that within the last twenty or thirty years such sudden floods, which often subside as quickly as they arise, have become more numerous and more extreme."

Referring to India Lord Hailey says, " Erosion in India is most serious in the foothills of its mountain ranges, where gullies and floods devastate large areas; but over and above this, great losses are being incurred by misuse of grasslands. They are lands which can maintain themselves only under conditions of reasonable treatment; persistent over-grazing has so impoverished them that in many cases the village herds are driven to treat the bush growth as a reserve, with grave consequences in surface erosion. The measures taken by the Indian Government have by no means been as energetic as circumstances required. It maintains the great forest reserves, mostly in the hills, which are the chief protection for the flow of the rivers, and consequently for the Indian irrigation system; but some large forest areas have been allowed to go back into village hands with the worst results. In some areas efforts are being made to reduce overstocking by directing attention to the improvement in the quality of cattle; large cattle-farms have been started,

and the castration of bulls has made considerable progress on a voluntary basis ; but in other respects the devolution of authority to local governments, and by them to local self-governing bodies, has left the country without any effective means of meeting a problem which is essentially one that requires a co-ordinated attack. Perhaps the one measure which affords a useful precedent for Africa is the Act passed in 1902 to enable the chos or gully erosion areas in the Hoshiarpur district of the Punjab to be closed periodically to grazing, with a view to allow for the re-seeding of natural grasses."

Seriousness of the problem in America can be judged from the following extracts from the Report of the Mississippi Valley Committee of the Public Works Administration, October 1, 1934 :—

" Erosion Control : It is only in comparatively recent years that the menace of soil erosion in the Mississippi Valley has been generally realized. Yet a large portion of the agricultural land in the basin has lost from 3 to 6 inches of top soil, and ' no less than 25 per cent of the tilled lands, have actually been stripped to the subsoil.' About 5 per cent has reached the gullying stage, and have been permanently ruined for agricultural use. Four hundred million dollars a year is a conservative estimate of the tangible loss in the United States.

" Erosion is insidious : The first stage is sheet erosion, often so imperceptible that the effect can be detected only by changes in the color of the soil or by an otherwise inexplicable lowering of productivity. Next comes, ' shoe-string erosion,' and finally gully erosion like the last stage

in an incurable disease. In the arid regions, and in seasons of drought in the normally humid areas, the wind may be an eroding agent: Witness the clouds of dust which were carried last spring from the Mississippi Valley over eastern seaboard cities. The very land is dying. Measured by man's brief generations it is losing for ever its ability to produce food.

" Meanwhile living standards on the afflicted land have dropped, farm tenance, tax delinquencies, bankruptcies and land abandonments have increased, and once smiling regions become a desolate testimonial to man's folly.

" Progress in erosion control may be measured by the 18,000,000 acres of farm lands terraced between 1915 and 1932, and by the large number of farmers who have been induced to use such measures of soil protection as improved tillage, crop rotation, and strip-cropping. But it has become apparent that soil protection cannot be left solely to education and self-interest. A national policy and programme is imperative.

" Public agencies should not be expected to do all the work but unless they intervene it is apparent that the work will not be done, or will not be done in time. Because the emergency is national the National Government must take the lead.

" The cost of protection against erosion is but a minute fraction of the cost of erosion. A twenty-year Federal programme, calling for joint action with States, countries, land districts, and individual owners, would cost the National Government $20,000,000 a year—5 per cent of the measurable annual loss from erosion at the present rate."

Control of catchment basin by an inter-state and inter-provincial organisation essential to ensure the continuance of civilisation.

9. As prevention is better than cure, it will be apparent from the above that in the programme for river conservancy, the first place should be given to the necessity for the control of the catchment basins. The old *Laissez-faire* policy, which might have been sufficient when the country was thinly populated and the needs of man were fewer, will no longer do ; but we have to take the necessary precautionary measures necessitated by the pressure of population and the advancement of civilization, if these rivers are to continue to serve the needs of man—an essential safeguard to ensure the continuance of that very civilization. It appears that neglect of such precautionary measures caused the decline of many ancient civilizations in the past as emphasized by Lord Hailey in the above Survey : " Erosion is believed to have played an important part in the decline of past civilizations. In Mesopotamia cities now buried in sand were once surrounded by thriving farms, and the degradation of rich and fertile land into desert—in some cases due, it has been suggested, to the silting up of irrigation works—is thought to have been a primary cause of the decay of a once thriving civilization. In ancient Greece the hill-tops, now bare, were thickly forested, and the hill-sides, now rocky and barren, were well protected with vegetation. Deforestation led to the stripping of topsoil from the hills and the consequent decline of Greek agriculture. Quantities of silt were deposited along the lower reaches of the rivers, and marshes and swamps were created, with the result that Malaria undermined the stamina of the people. The sterile rocky hills and bare deserts of Palestine, that hem in a small strip of cultivated coastal plain,

were once relatively fertile and provided good grazing for cattle and sheep."

As a river cannot be treated piecemeal but must be studied as a whole system, and as our major rivers flow through several provinces and states, it is apparent that the controlling work must be entrusted to an inter-provincial body.

Harmful effect of excessive withdrawal of river supply for irrigation.

10. Another inter-provincial aspect of our river problems that I would like to refer to in this connection is the harmful effect on a river regime that may result from excessive tapping of its supplies for purpose of irrigation. The most difficult problem that an engineer has to face in connection with the maintenance of a canal is with regard to the transportation of its silt burden. A lot of researches have been made in this connection the object being to exclude silt from the canal as much as possible. I don't deprecate this object nor the improvements in the designs that have been effected to achieve it ; but what I wish to emphasise is that the silt excluded from the canal is left in the river which it has to transport with the help of its gradually diminishing flow as the quantity of water extracted by the various canals, existing or prospective, increases. It, therefore, follows that there is a limiting stage beyond which it would be imprudent to tap a river for purposes of irrigation for, if it is unable to carry its silt burden, it is bound to deteriorate.

Need for control by an inter-state and inter-provincial organization.

11. It will probably take years before the deterioration reaches a sufficiently acute stage to affect the utility of the canals but, in view of the above considerations, I do not think there can be any doubt that excessive irrigation from any particular river may lead to this result. As in the matter of river conservancy we must take a

long view, it seems necessary to ensure that beyond the above limiting stage no irrigation is permitted from any river. The limiting stage for each river will have to be settled after careful observation and research and, if need be, with the help of experiments on models preferably, by the Standing Commission which, as I have recommended, should be constituted for each major river system. The principle underlying this preventive measure is a fundamental one on which depends the continuance of civilization, *viz.*, that though man has undoubtedly the right to enjoy the gift of nature he must not exercise this right in such a manner as to jeopardize the enjoyment of the gift by future generations.

12. This naturally leads to another important principle of inter-provincial character, *viz.*, that unlike air and light, when the gift is of limited quantity, as in the case of river supply, no particular province or state should be allowed to take advantage of its geographical position and monopolize this gift, but it should be equitably distributed among all the riparian owners having regard to their varying needs. Excessive extraction of river supplies for purposes of irrigation in the upper provinces naturally results in corresponding diminution of supply available for the lower provinces, and though this may not be objectionable during floods when usually there is sufficient supply available to meet the requirements of all, it may be a matter of serious concern during the dry season, specially, as owing to pressure of population and to meet the growing needs of advancing civilization, there are forces in operation which are tending to diminish the dry weather flow of rivers as explained above.

For river conservancy and for equitable distribution of this essential gift of nature.

13. It has already been explained that sufficient supply of upland water, specially in the dry season, is an essential requirement for the preservation of the tidal channels in Bengal and to push down the salt water limit which is tending to advance up the delta. In fact the lack of this dry weather flow is mainly responsible for death and deterioration of many of our tidal channels in Bengal causing serious concern to the Government in the matter of drainage, reclamation of low tidal areas and navigation. And as regards navigation, it is not only Bengal that is affected but also the neighbouring provinces of Bihar and Assam as a considerable portion of their produce is transported by water. Equitable distribution of the available river supply is, therefore, an essential requirement of river conservancy and as conflicting interests are likely to arise for adjudication, the work should be entrusted to an independent Standing Commission which should be constituted for each major river system traversing more than one province.

Floods

Spill area essential for maintenance of rivers in deltaic area.

14. Hitherto I have dealt with the subject of river conservancy with reference to positive services rendered by rivers to man in respect of irrigation, navigation and drainage. I now propose to refer to its other aspect which is mainly negative, *viz.*, controlling measures necessary for protection against floods. I have said " mainly negative " deliberately as in some areas, for instance, in deltaic Bengal, flushing of land during floods is not only necessary to raise and fertilize

the land and in the interest of public health, but this very process is essential for the conservancy of the river itself. I have already explained how rivers maintain themselves, if left to nature. As a man requires certain area of land to house and nourish himself and to meet his various needs, as a cow needs a certain grazing ground, so does a river require a certain spill area where it could relieve itself of a portion of its silt which would otherwise deposit in its bed and would gradually deteriorate it. This is very true in the deltaic region where, owing to flatter gradient and consequently comparatively less velocity, the river is normally unable to transport its silt burden during floods; and the works carried out in the past in defiance of this fundamental principle of river conservancy, have not only caused deterioration in the river channels making their maintenance more and more difficult but have also made the very problem of protection against flood damages, which they were intended to solve, more and more acute. Even in the non-deltaic region though the general country is usually higher than the flood level, there is certain spilling zone allotted by nature to most of the rivers and it is the encroachment by man, into what is essentially the river's domain, that has given rise to the flood problem in its present acute form.

Embankment cannot be a permanent remedy against floods.

15. The most common remedial measure adopted against floods is the construction of marginal flood embankment and as the deterioration it causes to the river channel and the drainage system, in public health and productivity of the soil, takes years to manifest itself, it has hitherto been universally accepted as the most effective protection against floods. If it were possible to imagine

a river with non-erodible boundary and carrying no silt, embankments would certainly have been a permanent remedy against floods ; but the problem is complicated by the all important silt factor, *viz.*, the silt which the river brings from its catchment basin as also the silt which it picks up from its erodible boundary on the way. In the economy of nature this silt is intended to be carried with the flood spill so that it could raise and fertilize the land and reduce the silt content in the river channel to what its velocity could transport. Confinement of the flood within the narrow river channel by means of embankments disturbs this arrangement and a portion of the silt, in excess of what the river can transport, deposits in its bed. This causes higher and higher flood level to carry the same volume of flood, necessitating higher and stronger embankment. So the deterioration of the river channel proceeds, until a stage is reached when it is no longer possible to offer protection against floods by means of earthen embankments.

It is like mortgaging the future generations to derive some temporary benefit for the present generation.

16. Embankment, therefore, offers no permanent solution to the flood problem. At best, it is only a temporary expedient and puts off the evil day to future generations when, owing to various vested interests and due to the deterioration of the drainage system, of public health and productivity of the soil, in consequence of the stoppage of beneficial flood spill from the land by embankments, problems are created which are almost insoluble. Even as a temporary expedient, it can hardly be considered as a sufficiently effective protection against floods as it is impossible to avoid breaches in earthen embankments and the destructive effect of concentrated

discharge through breaches is more serious than gradual inundation, specially, as the flood level relatively to the land gradually rises as a consequence of the embankments. It no doubt takes years before the evil effects of embankments are actually felt ; this very fact makes them rather risky expedients as vested interests are created which stand in the way of any bold solution being adopted in future. As I shall mention later in the course of these lectures, in Bengal, where the embankments were perhaps constructed the earliest in India as a protective measure against floods, their evil effects have already manifested themselves rather seriously as in several parts, tracts, formerly healthy and prosperous, have now become hot beds of malaria owing to the deterioration of the drainage system ; land is lying fallow owing to the growing decrease in the productivity of the soil and population is declining. In fact, having regard to our experience in Bengal, construction of flood embankments as a flood controlling measure would be like mortgaging the future generations to derive some temporary benefit for the present generation. It cannot, therefore, be recommended except perhaps for the protection of important vested interests where there is no other alternative.

Permanent flood-controlling measures.

17. Eliminating flood embankment from consideration the other controlling measures against floods that could be thought of, must necessarily apply to the causes of floods. No control is of course possible against the elementary causes of floods, *viz.*, rainfall and melting of the snow, nor over other natural factors which are tending to raise the flood level, such as rise of spill area and

the consequent reduction of its flood absorption capacity. But it should be possible to control factors created artificially by the acts of man, such as (*a*) excessive run-off from the catchment basin and soil denudation caused by extensive, often indiscriminate, deforestation, etc., perhaps the most important preventive measure as it attacks the flood problem at its source ; (*b*) curtailment of spill area by embankments and reduction of waterway due to obstructions such as inadequate bridge opening, etc. It should also be possible (*c*) to improve the spill channels, where available, so as to increase the waterway for the passage of the flood and to keep the drainage system in efficient condition so that the land which has been flooded can be drained off as quickly as possible.

18. I have already dealt with (*a*) and (*b*). Regarding (*c*) to which I attach considerable importance, it should be remembered that since the destructive effect of flood depends not so much on its volume as on its level, the aim of all controlling works should be to lower the flood level, just the reverse of what is effected by the flood embankments. It, therefore, follows that the most effective controlling measure against flood is to provide as much waterway and to allow the flood to spread over as large an area as practicable. Improvement of spill channels will not only increase the waterway in the channel sections and increase their discharging capacity but will also increase the water spread over the spill area which, partly due to its flood absorption capacity and partly by cross country flow, will help in lowering the flood level. And this very process will also help in maintaining the drainage system in an efficient

condition owing to its continuous flushing by clear water as the spilled water, after depositing the silt on the land, is drained towards the sea.

19. It may appear to be paradoxical that as a protection against floods I am advocating a measure which will spread the flood over even a larger area. A little consideration will, however, show that in most of the cases flooding by itself is not an evil; in fact it is necessary in the interest of public health and productivity of the soil, and as I have already explained, also for the conservancy of the river and drainage system of the country. What make it destructive are (*a*) its sudden invasion of the countryside, (*b*) the excessive depth of flooding and (*c*) the difficulty in draining the flood water. This is aptly illustrated by the condition prevailing in Eastern Bengal which is gradually inundated by the spill of the Ganges and the Jamuna during monsoon, and as a result of this annual flushing and the deposit of the highly fertilizing silt, the country is healthy and prosperous. In fact it is perhaps one of the most productive tracts in India.

Flood is not necessarily an evil.

20. Being accustomed to annual flooding people of Eastern Bengal build their houses on earthen mounds and adjust their agricultural practice to suit the flood condition instead of trying to control the flood artificially to suit agriculture, which, it seems to me, is a wrong way of dealing with the matter and converts what might otherwise prove to be a natural blessing, into a calamity. Instead of sudden onrush of the flood into the country as would be caused by concentrated discharge

It is a blessing in Eastern Bengal.

through breaches in flood embankments, there is gradual inundation and the drainage system is also naturally maintained in efficient condition due to the scouring of the silt in the river beds and other drainage channels by the copious flow of clear spill when it is drained towards the sea after depositing the silt on the land.

Inter-Provincial Commission

Preventive and remedial measures against floods.

21. I am, therefore, of opinion that the most effective preventive measure against floods is to prevent the harmful acts of man within the catchment basin so as to reduce the rate of surface run-off which determines the intensity of floods. After the flood has entered the river channels the most effective remedial measure against flood damages is to allow the flood to spread over as large a portion of its spill area as possible and not to oust it from what may be called the river's domain, by means of controlling works. If man must share this domain with the river he must adapt his needs so that they may not come into conflict with those of the river.

Need for an inter-provincial and inter-state organization to control the catchment basin so as to stop the mischief at its source.

22. Again, since the services rendered by a river, whether for domestic supply, for irrigation or for navigation, depend not so much on its monsoon flow, which is usually much more than what can possibly be utilized, but rather on the flow that it can maintain throughout the year, it will be clear from what I have said before that the most important conservancy measure is to prevent further accentuation of the inequality of distribution

of river-flow which, to a great extent, is already inherent in the problem, specially, in tropical countries owing to erratic distribution of rainfall, by stopping the mischief at its source, *i.e.*, by controlling the catchment basins. It will no doubt be hardly practicable to stop altogether the encroachments made by man into what may be called the "River's Domain." Room must be found for the growing population: increasing demands of the advancing civilization have got to be met. But along with the progress of civilization our knowledge of the physical sciences has also made considerable progress. With the aid of this knowledge to guide us and by concentrated study and research it should be possible to devise and execute suitable measures so as to reconcile the growing needs of man with those of the river, provided a suitable organization is set up with adequate authority and resources to tackle these problems seriously. Isolated action in a particular section of the river is not sufficient. What is required is a comprehensive and well planned attack on the problem as a whole. Nature does not recognize artificial political boundaries and where these prove an obstacle in the way of executing comprehensive measures, the obstacle must be removed by suitable legislation. Though this might infringe on the rights given under the Provincial Autonomy it has to be acquiesced in the larger interests of the Provinces and States and for the future of civilization.

23. In support of the views expressed above and to indicate how the problem is being tackled in an advanced country like the United States I quote below the following extracts from the Report of the Mississippi Valley Committee of

How the problem is being tackled in the United States.

the Public Works Administration, October 1, 1934 :—

* * * *

" I. *Land, Water and People.*

The time has passed when isolated or unrelated plans were adequate to American needs. When one strand in the interwoven web of our national fabric is touched every other strand vibrates. Land, water and people go together. The poeple cannot reach the highest standard of well-being unless there is the wisest use of the land and water."

* * * *

" II. *Water in Motion.*

A drainage basin, big or little, is a region through which water moves. No act of man can permanently halt this flow of power, nor even diminish it to an appreciable degree. The water must come down—we could not stop it if we would. We can, however, figuratively as well as literally, canalize it so that it will do what we want it to do and not do what we do not want it to do.

" *The Problem of Control* : The ideal river, which would have a uniform flow, does not exist in nature. Something usually has to be done, to equalize the flow or to take advantage of variations in flow, if the stream is to resemble even remotely an ideal river. But before this stage can be reached the question has to be answered : for what or for whom is the river to be ideal ? The problem of control involves not only the

physical nature of the stream, but the often conflicting claims of various uses and various users. Scientific planning requires a use pattern for each community, district, or region, as well as a geographical pattern which will reflect as fairly as possible the dominant needs of each locality.

* * * *

" Floods pay no attention to political jurisdictions. Any co-ordinated system of control will demand the co-operation of neighbouring States with each other as well as the co-operation of States with the Federal Government. Obviously the Federal Government should bear its share of the costs and the responsibility. Obviously, too, the States should do the same. To make this easily possible we need uniform State flood control laws, Federal legislation to expedite inter-state compacts, and a permanent policy of Federal participation based on accurate estimates of the benefits to be derived. The integrity of State and local Governments is certain to be impaired if the Federal Government is regarded as a kind of Santa Clause.

" It is suggested that the Federal Government might pay 30 per cent of the cost of labour and materials for projects of chief benefit only to local communities ; a larger proportion as the measurable general benefits increased ; and 100 per cent of the construction cost when the benefits to be derived were, as they are now recognized to be on the lower Mississippi and its back-water areas, a national affair. In each instance there should be responsible and legally constituted local agencies with which the Government could deal.

The same principles that are applied to flood control may be applied to low-water control.

* * * *

" *Interrelation of Interests.*—As communities increase in population, extent and complexity, new and far-reaching agencies have to be called in or created to deal with their water problems. The family well gives way to a city water system, that in its turn, perhaps, to a district or sectional water system. In time, as the present report suggests, a national programme is required to reconcile the needs of the 49,000,000 people who live on the 12,35,000 square miles of the Mississippi River System. The multiple uses of water add to the intricacy of the problem.

" There consequently should be a revaluation of controlling agencies, both local and general. Where the physical problem to be attacked transcends existing political boundaries, new types of regional organization, such as the New England Council or the Ohio River Board of Health Commissioners, have already appeared. Other types are the " Authority," or publicly owned corporation, of which the Port Authority of New York is an example ; the inter-state conservancy district agencies set up by two or more states under inter-state compacts, and Regional Authorities set up by the Federal Government, for which the Tennessee Valley Authority may be regarded as a precedent.

" Either on its own initiative or on request from the States, the Federal Government should stand ready to investigate projects or situations. In planning and carrying out actual operations the

benefits and responsibilities should be as accurately assessed as possible as between the National State and local Governments. The Federal Government's responsibility should not be too narrowly interpreted, since it is, in practice and by the terms of the Constitution, accountable for the general welfare. Measurable benefits are not always the criteria which can be set up. "The ideal allotment of costs will be that which will produce the best total economic effect within the limits of public support and of administrative practicality, with due regard to all equitable considerations."

24. As all our major rivers originate in regions beyond the political boundaries of Bengal the organization required to tackle these problems must necessarily be Inter-Provincial. Again, in the case of some of them a large portion of the catchment area lies in Native States which are under the political suzerainty of the Government of India and also in Nepal which can only be persuaded to join the above organization by the Government of India. In the case of the Ganges for instance, of which some informations are available, the catchment areas are distributed up to its confluence with the Brahmaputra at Goalundo approximately as follows :—

British India	..	..	1,72,000 sq. miles.
Indian States	..	..	1,06,000 ,, ,,
Tibet & Nepal	..	..	70,000 ,, ,,
	Total	..	3,48,000 ,, ,,

Say 3,50,000 sq. miles.

It may be mentioned that it is in the native States and in Nepal where there is hardly any organized Engineering or Forest Department that,

comparatively speaking, control is more urgently called for.

Progress so far made.

25. It will, therefore, be apparent that what is required is an Inter-Provincial and Inter-State Organization for each major River system to be established by a statute enacted by the Government of India in consultation with the Provinces and States affected and with adequate power and resources to be able to deal with these problems seriously. We have already made some progress with regard to the constitution of a Ganges River Commission. The proposal has been accepted on principle by the Governments of Bengal, Bihar and United Provinces and an Interim Committee consisting of three Chief Engineers of these Provinces, a Senior Officer representing the Forest Department and another Officer representing the Railways, has been formed to frame the necessary constitution, and pending the establishment of the Commission, to discharge its functions as far as possible.

Need for a whole-time and independent Chairman and permanent Secretariat.

26. As these officers are all busy with their normal departmental work they hardly find any time to think out these problems. What is required is a whole-time Chairman having wide knowledge of these rivers and their problems, solely engaged on this work, who should, so to speak, constitute the brain of the Commission and, assisted by a permanent Secretariat, think out these problems and take the necessary initiative for their solution. It will be for him to suggest these measures, including the collection of the requisite data, to the Commission consisting of representatives of Provinces and States, which should meet periodically so that their view points and the vested interests that are likely to be

affected and how these could be reconciled with the requirements of the river conservancy, can be thoroughly discussed, and a plan of action laid down by the Commission as a whole. Again, having regard to the nature of the problem that has to be tackled and the long term programme that must necessarily have to be followed for its solution, it will be apparent that continuity of policy is essential. This, however, it will be impossible to secure without a permanent Chairman appointed for a term of years and a permanent Secretariat, as the representatives of the Provinces and States, must necessarily be seniormost officers of the departments concerned and being on the verge of retirement, will soon be replaced by their successors in office.

Ganges River Commission

27. Having regard to the above considerations my suggestions as regards the function and constitution of the proposed Ganges River Commission are as follows. Subject to necessary modification these should also apply to the proposed Commission for the Brahmaputra and Meghna rivers which the Governments of Bengal and Assam have agreed to constitute.

Function of the proposed Commission

28. *Function* : Since the proposed Commission has to deal with all questions concerning the conservancy of the Ganges river system, its function should include among others—to be gradually defined as experience is gained from its actual operation—all measures necessary for :

(*a*) prevention or at least mitigation of destructive floods :

(*b*) maintenance of navigation at least in reaches which are now navigable :

(*c*) conservation of dry weather flow.

In view of the extensive damages that have been caused in all the affected Provinces by the floods in recent years item (*a*), *i.e.*, preventive measures against floods is really the most important, and, to a great extent, it also includes items (*b*) and (*c*) as the best and the most suitable means of preventing destructive floods is to take recourse to measures which will decrease the surface run-off and increase the percolation flow within the catchment basin or, in other words, increase the sub-soil storage which will help in distributing the total precipitation more equitably throughout the year. The Commission should, therefore, lay special emphasis on the necessity to control the catchment basin, *i.e.*, devising and executing suitable measures so as to reconcile the needs of man with those of the river.

29. The most important measures regarding (*b*) and (*c*), *i.e.*, maintenance of navigation and conservation of dry weather flow will thus be necessarily included in the measures taken under item (*a*) as explained above. Other measures should, in my opinion, include ‘ bandalling ’ which is now being done by the Steamer Companies with a subsidy from the local Government and which, after the Commission is constituted, will have to be controlled by that body and dredging, if necessary.

Again, to be able to discharge these functions it will be necessary for the Commission to see that nothing is done in the Provinces which is likely to have any adverse effect on any of them.

For this purpose the Commission will have to scrutinize at least the main outlines and not necessarily the details, of any scheme above a certain specified limit that the Provinces may propose to execute in future.

30. The Commission will also have to take a stock of the data already available and consider what further data have to be collected. Another important function of the proposed Commission would be to standardize the method of collection of data in the Provinces concerned and to arrange for their statistical analysis so that they may serve as indisputable evidence in the deliberation of the Commission or if the necessity arises in future, in connection with the settlement of any inter-provincial dispute with regard to water rights.

31. The following data would seem to be necessary. These will no doubt be supplemented as a result of subsequent experience gained by the Commission :—

(*a*) Gauge reading at frequent intervals along the Ganges and her tributaries and branches.

(*b*) Discharge observations taken at strategic points together with silt-observations.

N.B.—These will also serve as standard cross-section sites.

(*c*) Survey of the main river, its main tributaries and branches showing the embankments—Railways, roads, etc.,—within the flood plane together with information regarding their heights, waterways available, etc. If no recent survey is available an aerial survey will have to be made.

It may be noted in this connection that an aerial survey of the Ganges from Rajmahal to Goalundo has recently been made in Bengal.

(*d*) Survey of the catchment basin specially the portions covered by the forest, both reserved and unreserved, and showing the area where soil denudation is already very severe and noting the positions of the rain gauge stations together with their mean annual and maximum intensity of rainfall.

(*e*) If sufficient number of rain gauge stations are not already available steps will have to be taken to establish new stations.

32. The next point to consider is whether those functions including the collection of data will be discharged directly by the Commission in which case it has to be empowered with the requisite executive authority and supplied with the necessary finance or it will serve merely as an advisory body making recommendations and expecting that the local Governments concerned should take necessary action accordingly. In this connection it would perhaps be relevant to refer to the history of the Mississippi River Commission. It appears that this Commission was first constituted by an Act of the Federal Government (passed on June 28, 1879) as an executive body reporting directly to the Secretary of War. This, however, resulted in dual Engineer Organizations, *viz.*, that of the Commission and the regular Engineer Department of the Federal Government and in 1928 the Commission was re-organized by the Flood Control Act of May 15, 1928. As a result " the Mississippi River Commission ceased to be an executive body and became an advisory and consulting body, charged with certain duties including the holding of public hearings, recommendations of policy, recommendations on general types of construction work, recommendation of

annual programme of work, and other similar duties." "The President of the Commission became the executive officer of the Commission reporting directly to the Chief of Engineers and responsible to him for the prosecution of the work."

The Commission should be an advisory body but to ensure that its reasonable recommendations are acted upon, it should be constituted by a statute enacted by the Government of India.

33. In view of the history of the Mississippi River Commission as briefly explained above and owing to the difficulty of providing the requisite finance if it has to execute the necessary works, I seem to think that the proposed Ganges River Commission should be constituted on the model of an advisory and consulting body rather than as an executive authority. But it seems necessary to take notice of an important distinction as between the Mississippi and the Ganges rivers in this connection. In the case of the former the Federal Government has undertaken the responsibility for its conservation by executing the necessary works with the help of its regular Engineering organization. In the case of the Ganges the Government of India has undertaken no such responsibility nor has it any Engineering organization of its own. Any work recommended by the Commission has necessarily to be entrusted to the local Government concerned for execution in the appropriate department. In view, however, of the present unstable political condition in the Provinces it seems necessary to devise some arrangement with a view to ensuring that reasonable recommendations of the Commission are acted upon by the Provincial Governments concerned. This could perhaps be secured by constituting the Commission by a statute enacted by the Government of India.

34. Though this is a point on which a decision can only be reached by obtaining authoritative

legal opinion it seems to me that the duties of the proposed Commission, *viz.*, "to deal with all questions concerning the conservancy of the Ganges river system," are much more comprehensive than what is defined in Item 19 of List II of the Seventh Schedule of the Government of India Act, 1935, as included in the Provincial Legislative List. If this view is supported by legal opinion Government of India can perhaps enact the necessary statute and constitute the Commission under its Residual powers of Legislation as given in Section 104 of the Government of India Act, 1935. I do not think it will suffice to have the necessary statute enacted under Section 103 of the Government of India Act as then the very object of having the Commission constituted under the authority of the Government of India as explained above may be vitiated by subsequent amendment or repeal by Provincial Legislatures.

Constitution of the Commission

How the Commission should function.

35. My view, therefore, is that the proposed Commission should be constituted by a statute enacted by the Government of India. It will be mainly an advisory and consultative body and discharge the functions, in their executive aspects, through the agency of the Provincial Governments and States concerned. The Commission will decide as to the measures, which, from a consideration purely of the technical aspects of the case, are necessary for conservancy of the river. Some of these recommendations the Provincial Governments and States concerned will no doubt agree to finance individually without

any assistance from other sources. As regards the other recommendations of the Commission, if any, these together with estimates of cost should be submitted to the Government of India. The Commission should also recommend as to the allocation of the cost as between the Provinces and States concerned having regard to the degree of benefit derived by them and the Government of India. If the Government of India accepts this recommendation, well and good, if not, it may consult the Central Board of Irrigation and issue necessary instructions to the Commission either accepting its recommendation or rejecting the same. If, however, the extra cost beyond what the Provinces and States concerned agree to finance, comes to be heavy, it will clearly be necessary to find out some source of revenue to enable the Commission to function efficiently. This is, however, a matter on which no useful suggestion can be made on a hypothetical basis but may perhaps be left to the Commission, when it is constituted, to decide on the basis of information that may be available then and make recommendation to the Government of India.

Need for an independent Chairman to be appointed by the Government of India emphasized.

36. It will be seen from the above that in addition to representatives from Provinces and States and other bodies such as the Railways, and Steamer Companies who are vitally interested in the conservancy of the Ganges river system there should be a representative of the Government of India in the Commission, independent of and in a position to reconcile the view points of the sectional interests. Besides, for efficient discharge of the functions as detailed above, occasional meetings of the representatives do not appear to be sufficient but there should be a permanent

whole-time organization prepared to devote its entire time and energy in executing the policy and programme laid down at these meetings.

37. The constitution that I can visualize should, therefore, be as follows :—

President—An experienced Engineer with wide knowledge of the rivers concerned to be appointed by the Government of India. He should be a whole-time officer appointed for a term of say 5 years. It will be his duty to see that the policy and programme of the Commission are acted upon with the least possible delay and, with the assistance of the Secretary and other staff, to exercise general supervision over the activities in this connection in the Provinces and States.

Members—

One representative each—An Irrigation Engineer preferably the Chief Engineer, Irrigation—to be selected by the three Provinces—Bengal, Bihar and U. P.

One representative of the Nepal Government.

One representative of the States.

One representative to be nominated by the Railway Board.

One representative to be nominated by the Steamer Companies who maintain regular Steamer Service in the Ganges.

One Forest expert and another expert on Agriculture to be nominated by the Government of India.

The Commission should have a permanent Secretariat with a permanent Secretary and a few technical and office assistants to start with to be expanded later as the necessity arises.

38. The cost of the above establishment should, I think, be borne partly by the Government of India and partly by the participating Provinces and States on a percentage basis as may be mutually agreed upon or in the absence of agreement, as may be decided by the Government of India. It may be mentioned in this connection that the Governments of Bengal and Assam have agreed, on principle, to constitute a Commission to deal with all questions concerning the conservancy of the Brahmaputra and the Meghna rivers and an Interim Committee has been formed to define its function and to frame the necessary constitution. As the work increases it will probably be necessary ultimately to have completely separate organisation for this and for the Ganges River Commission. But to start with, as a measure of economy, the two Commissions may perhaps function fairly efficiently with the same President and the Secretariat.

The proposed Commission will facilitate prior consultation and perhaps secure agreement among the Provinces and States concerned as regards prospective schemes.

39. In this connection it may be mentioned,—and this may perhaps serve as an additional argument in support of the contention, that the Government of India should actively participate in the constitution of the Commissions for these major rivers,—that recently the Government of India addressed the Local Governments drawing their attention to the implications of Sections 130 to 133 of the Government of India Act, 1935. It was suggested that to avoid Inter-Provincial disputes with regard to water rights the Provincial Government before executing any scheme

which is likely to interfere with water supplies of any other Province from any river should consult the latter. Constitution of a Standing Commission with its function as proposed above will facilitate such consultations and as the Commission will consist of the chief technical advisers of the local Governments concerned, it is very likely that this will lead to agreement and it won't be necessary to make complaint to the Government of India as contemplated in Section 130 of the Act. In the event, however, of the unusual contingency of such a complaint being made the Standing Commission may as well serve as the Commission proposed to be appointed under Section 131. With its accumulated knowledge and experience of the river as a result of intensive study, such a Standing Commission will, it seems to me, be more competent to deal with such matters than any temporary Commission appointed for the time being.

Services rendered by the Rivers to Bengal and their problems

The most important services rendered to Bengal by her rivers.

40. *Formation of the Delta* :—The major portion of Bengal is deltaic and the most important service rendered by her magnificent river systems was to create the land and to raise it through centuries so as to make it fit for human habitation. Though all the rivers having their sources in the hilly regions lying to the west, north and east made their contributions in this respect depending on the volumes of water they carried and the quantities of silt they could transport, by far the

greatest contribution was of course made by the Ganges and her tributaries. In this connection it would be of interest to note the views held by the Geological experts regarding the origin of the Gangetic delta.

Messrs. Haydon and Pascoe * of the Geological Survey of India state, " the absence of tertiary marine deposits, and the presence of tertiary fresh water deposits, throughout the outer Himalaya from Dehradun to Sikkim show that, since the elevation of the Himalaya, marine conditions have not existed in that area, nor is there any evidence of the existence of such conditions at any point in the Gangetic plain between the Himalaya and the Peninsula." They admit that the evidences in support of this theory are rather meagre being a few borings at Ambala, Agra, Lucknow, Chandernagore, Fort William and Canning, the deepest of which was only a little over 1,300 feet deep. But they argue that in the absence of any evidence in favour of a contrary view it would not be safe to reject the generally accepted conclusion, " That the conditions prevailing over the Indo-Gangetic plain from comparatively early tertiary times have not been dissimilar to those that exist at the present day," and that there has been a slow but gradual subsidence permitting of the accumulation of an enormous mass of alluvial deposits." In the " History of the Rivers in the Gangetic Delta " Mr. C. Addams-Williams, C.I.E., late Chief Engineer, Irrigation Department, has also given prominence to this view, " That before the present upper strata of the delta were laid down, it appears

Enormous alluvial deposits.

* Report on the Hooghly River and its Head Water, 1919.

that there was an older delta composed of materials totally different to those deposited by the Ganges. A stratum of yellow clay and sand appears to underlie that upper and newer strata of blue clay and sand. At Cowkhally on the lower Hooghly the yellow clay is about 60 feet from the surface as shown by borings taken in 1914. At Kushtia there are outcrops of the same stratum and the general outcrop appears to be roughly round the extreme edges of the present delta." Mr. Addams-Williams concludes, " It appears that this delta was laid down by the rivers issuing from the north or north-east, and that presumably the Ganges had not then become a factor in the case. The old delta was depressed and the Ganges appears to have then entered on the scene and began forming the new delta on the top of the old from the neighbourhood of Rajmahal."

The present delta built up and raised by the silt carried by the rivers.

41. But whatever may be the justification for this theory, it seems certain that the land we live in, up to a depth that we need think of, was built up and gradually raised through centuries by the silt carried by the rivers mainly from the Himalayas and partly from the Chota-Nagpur and Sonthal Parganas hills. To appreciate the services rendered by them in the past, which they are still rendering in portions of deltaic Bengal and would have been rendering in the rest but for human interferences and other reasons, as I shall explain later, it is necessary to envisage how these rivers, specially the Ganges, which by far is the principal delta builder, functioned in that early age and are still functioning in building the land and in raising and extending it towards the sea. The process of raising and extension of the delta towards the sea has been going on for

How the delta was formed.

thousands of years, and it will probably continue for an indefinite length of time as the stock of building material, *viz.*, detritus, carried with the rainfall over thousands of square miles of catchment area including a considerable portion of the mighty Himalaya, is almost unlimited.

42. Millions of tons of this silt are thus being transported every year by the strong current of the Ganges flood and brought down to its mouth where the current being checked by coming in contact with the sea, the silt in suspension drops into the bed. Land was thus formed at the head of the delta and as it began to extend the Ganges, like the other delta builders began to approach the sea in several diverging branches enclosing and intersecting the delta already built so as to raise it in the quickest possible time, and to extend it towards the sea in ever-increasing width. Each branch carried its due share of the silt laden flood and as the bank on either side was low to start with, it was inundated during floods with the result that silt carried in suspension dropped on the bank which was thus gradually raised, the raising being more rapid nearer the river.

Thicker deposit close to the rive

Along with this process of raising of the delta already built so as to make it fit for human habitation, the other important function of extending the delta towards the sea was being carried on by the main volume of the floods, carried down the several diverging branches, dropping their silt burden near about their mouths.

43. Now mere extension of the delta towards the sea-face would not be of much use but what is required is that it should be sufficiently raised so as to be fit for human habitation and cultivation. If the task of raising the delta was left entirely

to the carriers of upland floods the process would have been exceedingly slow as we can expect these floods only during the monsoon months, *i.e.*, only in 4 out of 12 months every year. It is, therefore, in the economy of Nature that the tides should come to our assistance in this respect. Tides flow up these rivers with strong velocity twice daily throughout the year and as there is a vast reservoir of unconsolidated silt at their mouths, deposited there by the upland floods during monsoon months, the tides pick up this silt almost to the saturation point on their way inland. So long as the banks of these rivers within tidal limits are below high tide level and the rivers are free to spill, the silt laden tides perform exactly the same function as the upland flood carriers, *viz.*, raising of the delta already built, with this difference that while the latter function only during the actual floods in the monsoon the beneficent activity of the tides continues throughout the year.

Tides help in raising the delta.

44. The second function of the tides is to fill up the interior of the delta lying between the upland flood carriers. As mentioned above, the depth of silt deposit by upland floods or by the tides carried up these rivers, is the maximum close to the river banks, where the velocity, which determines the proportion of silt that can be carried, is first checked, and as the spilling proceeds away from the river banks, the silt content of the spilled water and consequently the depth of silt deposit is less and less. Now, if Nature had to depend entirely on this agency, the area lying midway between the continuous upland flood carriers would have remained low, probably in the shape of creeks extending from the

sea, till these rivers, after performing the function of raising the banks close to their channels, would burst through these banks and divert along these low valleys. This would have been a slow process and to facilitate the work of delta building, here also Nature requisitions the services of the tides which, picking up the silt on their way up these creeks or tidal rivers, gradually raise their bed and banks until they are raised up to high tide level and rendered fit for cultivation. The source of this silt supply is no doubt what has been carried to the sea by the upland floods for ages, but the tides, by their constant movement, keep it in an unconsolidated state and distribute it all along the delta-face between the two main estuaries, *viz.*, those of the Hooghly and the Meghna.

Two agents employed by Nature—upland flood-carriers and the tides.

45. It will be clear from the above that Nature has been employing both the agents, *viz.*, the upland flood-carriers and the tides in her work of delta building. She has been assisted in her task by two favourable factors, *viz.*, the steep slope of the Himalaya, the highest mountain in the world, which has been furnishing the building material in abundance during the monsoon months, and the abnormally high tidal range, due to the funnel shape of the Bay of Bengal, which has been helping in distributing these materials twice daily throughout the year. But though the abnormal tidal range at the delta-face has been so helpful in raising the delta, in fact, raising it higher than what would have been possible if the range was lower, this very fact has stood in the way of rapid extension of the delta towards the sea ; for owing to the high tidal range more and more of the alluvium, brought down into the sea

by the upland flood-carriers, is being dispersed along the delta-face, to be picked up by the tides travelling inland through innumerable tidal channels, and less and less of it has been deposited in a consolidated state to extend the delta.

High tidal range helpful to navigation.

Function of rivers in Bengal.

46. High tidal range has also been helpful in the interest of navigation, and it is no wonder that the people of Bengal look upon the rivers, both tidal and non-tidal, with veneration, for, they created the land, are draining and fertilizing it and are helping in carrying the produce. Fertilization by tidal silt may not be apparent, but as the source of this silt is really what is carried by the upland floods, the manurial properties of which are so highly valued, it is only a question of time, till the salt carried with the tidal silt has been washed away by rains, before its fertilizing properties are manifested, as is so amply demonstrated in the case of the reclaimed lands in the Sunderbans.

Rivers are an essential factor in rural development.

47. Bengal being mainly an agricultural country the rivers are thus the principal source of economic well-being of the people and where they are still active and are performing their original functions, as in East Bengal, the people are healthy and prosperous; where they are deteriorating and their beneficial activities have been interrupted, either due to natural causes or due to human interference, as in Central, Western and Northern Bengal, the area is progressively deteriorating both as regards health and productivity of the soil. River problems in Bengal are thus virtually the problems for the Rural Development in Bengal and have to be solved if she has to be saved from reversion to swamps and jungles from which she was

reclaimed by the rivers, specially in her western and central parts, which even as late as a century ago used to be very healthy and prosperous.

48. *Rivers classified.*—It will perhaps be convenient at this stage to classify the Bengal rivers, having regard to their special characteristics, into the following groups :—

Group I or Perennial Rivers : Primary delta builders originating from the Himalayas, maintaining more or less perennial flow, and navigable, at least in their lower reaches. Owing to the large catchment areas which they drain they can count upon a fair incidence of rainfall occurring in some portions or other in their basins practically continually throughout the monsoon. Partly for this reason and partly because of the melting of the snow at the higher altitudes in these basins they remain in floods throughout the monsoon months, gradually rising in level in June and beginning to subside after the middle of September. Even after the subsidence of the floods they maintain a fair amount of flow throughout the dry season so necessary for irrigation, navigation, etc., thanks to the extensive forest areas comprised within their catchments, which help in increasing the subsoil storage during the rains to be released gradually throughout the year. For this reason their outfalls, which are tidal, are usually maintained better than in case of rivers of other groups.

49. The principal rivers in this group are (*a*) the Ganges series including the tributaries and the spill channels, (*b*) the Brahmaputra series including the Teesta, and (*c*) the Meghna. By far the most important delta builder is, of course, the

Ganges which, traversing a length of 1,540 miles and draining an average annual rainfall of 42 inches over a catchment area of 3,50,000 sq. miles and with the recorded maximum flood discharge of about 20,00,000 cusecs (at Sara), has been mainly responsible in building, raising and fertilizing the delta. The Brahmaputra was originally a comparatively small river, but since its connection with the Tsanpo of Tibet through its tributary the Dihong (in Upper Assam) and subsequent additions of the floods of the Teesta (since 1787), it has been a formidable rival of the Ganges and promises to play a more and more important part in future. It now traverses a length of 1,800 miles and drains an average annual rainfall of 88 inches (in Assam valley) over a catchment area of about 3,61,000 sq. miles.

50. Though the Meghna does not drain such extensive areas as the Ganges or the Brahmaputra, it comprises within its catchment basin Cherrapoonjee and other wet areas which have probably got the highest records of rainfall in the world. For this reason it remains in fairly high floods throughout the monsoon and maintains a fair amount of flow even during the dry season, permitting navigation by the Despatch Service steamers for a considerable length from its mouth as in the case of the Ganges and the Brahmaputra. The Meghna, however, does not carry much of silt, and whatever it carries from its catchment basin, is mostly utilized in raising the vast depression known as Sylhet *jheel* extending into the Mymensingh and Tippera districts practically up to the Bhairab Bazar Railway Bridge, and the flood that flows down the lower reaches is practically silt-free.

51. *Group II or Torrential Rivers* : Primary delta builders originating from the low hills of Chhota-Nagpur and Sonthal Parganas, such as the Damodar, the Ajay, the More, the Cossye, etc. Unlike the rivers of Group I their catchment areas are localized in comparatively small blocks, without any marked variation in the distribution of rainfall from one portion to the other. Consequently, their flow is torrential, that is to say, when there is heavy rain in one part, it usually rains heavily throughout the entire catchment, causing high floods in these rivers. The floods, however, are short-lived, usually lasting not more than 3 or 4 days at a time, as when the rain ceases, it usually ceases simultaneously over the entire catchment and these rivers may dwindle down to a mere trickle sometimes even during the rainy season, while during the dry season they run practically dry. Another reason for such an erratic distribution of flow in these rivers appears to be that as their catchment areas comprise perhaps one of the oldest parts of India, the hills have lost a good portion of their soil cover due to surface erosion caused by rainfall for thousands of years, thus considerably reducing the subsoil storage capacity. Deforestation is also perhaps going on more extensively in these areas, further reducing the subsoil storage which is the agent employed by Nature to compensate against the erratic distribution of rainfall, moderating the intensity of floods and helping to distribute the total available flow more equitably throughout the year. All these factors combined have given these rivers their torrential character, often causing disastrous floods during the monsoon while during the dry season there is hardly any flow to serve the

needs of man. Again, owing to the lack of pressure of sufficient flow from above, except during the floods, their lower reaches usually get choked with tidal silt where the outfalls are tidal, as in the case of the Damodar, or due to the back rush of the Bhagirathi flood, as in the case of the other rivers of this group which fall into the Bhagirathi river. This further aggravates their flood problems.

52. It will be clear from the above that the contribution of these rivers towards the building of the delta could not have been much compared with the rivers of Group I. It appears that the eastern portion of Burdwan district and the western portion of Hooghly and Howrah districts owe their origin to the delta building activity of the Damodar, which is the most important of this group of rivers with a catchment area of 7,200 sq. miles and a maximum flood discharge of the order of 6,50,000 cusecs, and the eastern portion of Midnapur district to that of the Cossye. Their value, however, lies in the fact that they constitute the only source available for supplying the water needed for artificial irrigation and for flood flushing.

Rivers originating from the low hills of Tippera and Chittagong districts, such as the Goomti, the Karnaphuli, the Halda, etc., may also perhaps be classed under this group. It may, however, be noted that unlike the West Bengal group they maintain a certain amount of flow even during the dry season sufficient for the purpose of navigation by country boats and, in the case of the Karnaphuli even for the purpose of navigation by sea-going vessels. This may be partly due to the heavy rainfall, a portion of which

precipitates even during the dry season and partly, it may be, because deforestation has not proceeded so extensively in their hill catchments as in case of the West Bengal rivers.

53. *Group III or Tidal Rivers* : Subsidiary delta builders, mainly the lower reaches of the rivers of Groups I and II within tidal limits which, as has been explained above, continue their beneficent activities of raising, fertilizing and draining the lower portion of the delta throughout the year and help in transporting the produce of the country.

River Problems with Reference to Health and Productivity of the Soil

Ancient prosperity of Bengal.

54. In all accounts that have been preserved from ancient sources Bengal is reported to have been healthy and prosperous. Bernier wrote, about the middle of the 17th century, " The knowledge that I have acquired of Bengal in two visits inclines me to believe that it is richer than Egypt." Even as late as 1815 Hamilton wrote of Hooghly, Howrah and Burdwan districts, which area is now one of the worst as regards health and impoverishment of the soil, as follows, " In productive agricultural value in proportion to its size, in the whole of Hindusthan Burdwan claims the first rank and Tanjore second." In her eastern parts, where she is being nourished by her rivers, Bengal still continues to be prosperous and healthy. Even in the rest of Bengal there is no dearth of water resources but the growing deterioration in the health and productivity of

Progressive deterioration due to faulty distribution of water resources.

the soil has to be traced to their faulty distribution. Through some streams more water flows than is necessary, frequently causing disastrous floods, and at other places decrease in flow through natural waterways has caused serious deterioration, in many cases rendering them even incapable of draining the countryside. Indeed, many of these streams, which were originally intended by Nature—this is a phenomenon peculiar to deltaic area—to spill over the land which they traverse, and keep it in health and plenty by supplying the rich silt of the Ganges, the Damodar, etc., have now been converted into stagnant pools of water, providing excellent breeding ground for mosquitoes, and many a district of Bengal, specially in the centre and in the west, has been rendered extremely unhealthy with steadily decreasing population and with land gradually going out of cultivation.

Faulty distribution due to human interference and natural causes.

55. This faulty distribution of the available water resources, which has brought about the present deplorable condition, is attributable partly to human interference with the natural process of building up of the delta and partly to natural causes. I have already mentioned, in the course of my lecture on the Inter-Provincial Aspect of our River Problems, how human interference in the shape of extensive deforestation, soil denudation, etc., within the catchment basin, mostly beyond the borders of Bengal, is not only tending to raise the flood level and diminish the dry weather flow but is also causing rapid deterioration in the river regime by bringing in more silt than what the flood current can transport. The most prominent instance of human interference within the borders of Bengal, which has mainly

affected the rivers of Groups II and III above, is to be found in the flood embankments mainly in Western Bengal but partly also in Central Bengal which, by cutting off the flood spill and depriving the land of natural manure, have killed the network of natural spill and drainage channels within the area and have brought about the present deplorable condition. The natural causes have mainly affected the rivers of Group I which, owing to the diversion of their original courses and consequent deterioration of the natural spill and drainage channels within the areas, as will be explained below, have caused serious deterioration in health and in the productivity of the soil in Central and Northern Bengal and in parts of Mymensigh district.

56. There is no dearth of natural hydraulic resources. In fact, Bengal has been highly favoured by Nature in this respect. Her rainfall, though somewhat erratic in its distribution in her western parts, is normally quite adequate to meet the requirement of at least the *khariff* crop in other parts, and she can count on abundant monsoon floods to nourish her soil with fertilizing silt and to kill the malaria larvae, if only these floods could be properly distributed. A more equitable distribution of her water resources is thus vitally needed for the rural development in Bengal. We now propose to go into the question somewhat closely, dealing with each group of the rivers separately and examining a representative type of each group in detail.

Solution lies in more equitable distribution of the abundant water resources available in Bengal.

57. *Rivers of Group I—Perennial Rivers—Major Changes in their Courses.*—The areas which have been adversely affected mainly due to natural causes, *i.e.*, by major changes

Major changes in the river courses—natural cases of deterioration.

in the courses of the rivers of this group, are (1) North Bengal due to the diversion of the Teesta towards the end of the 18th century (1787), (2) portions of Mymensingh and Dacca districts due to the diversion of the main Brahmaputra through the present Jamuna channel in the earlier part of the 19th century and (3) Central Bengal due to the diversion of the Ganges through the Padma sometime towards the beginning of the 16th century. There is no controversy as regards the changes in the courses of the Teesta and the Brahmaputra river, as they occurred comparatively recently and can be definitely proved by reference to Rennel's maps which were prepared earlier.

North Bengal

Diversion of the Teesta—cause of deterioration in North Bengal.

58. *Diversion of the Teesta.*—Rennel made his survey between 1764 and 1777 and his maps are the earliest authentic maps of Bengal in existence. In these maps the Teesta (probably derived from Trisrota or flowing in three channels) is shewn as flowing through North Bengal in several branches Purnabhaba, Atreyi, Karatoya, etc. All these streams combined lower down with the Mahananda, now the westernmost river in North Bengal, and taking the name of Hoorsagor finally discharged into the Ganges at Jaffarganj near modern Goalundo. The Hoorsagor river is still in existence, being the combined outfall of the Boral, a spill channel of the Ganges, the Atreyi, the Jamuna or Jamuneswari (not the main Jamuna through which the Brahmaputra now flows) and the Karatoya, but instead of falling into the Ganges,

it falls into the main Jamuna, a few miles above the confluence of these two rivers at Goalundo. The Purnabhaba is now a tributary of the Mahananda, and the latter river no longer flows through the Hoorsagor but has an independent outfall into the Ganges near Godagari.

59. It will be seen from the above that the Teesta, with the help of her several branches and the Mahananda, built up the North Bengal. Having regard, however, to the large tract of land comprised within North Bengal, it seems probable that some other rivers also helped in the process in the olden age. In this connection it would be interesting to refer to the valuable paper read by James Fergusson before the Geological Society of London in 1863. He reproduces Rennel's map of the rivers in Bengal, showing therein the probable changes which occurred in the courses of some of them before Rennel's time and since. According to Fergusson the Koshi, which now falls into the Ganges near Bhagalpur, used to flow through North Bengal and combine with the North Bengal river system referred to above in their lower reaches. The Koshi, therefore, might have contributed to the building up of the southern portion of North Bengal. Again, Fergusson hints at the possibility of the Brahmaputra flowing through North Bengal once before, *i.e.*, before its travel eastward through the Mymensingh district to meet the Meghna. Having regard to the fact that changes in the courses of deltaic rivers are not only inherent in their conditions of flow but necessary for the building and raising of the delta, I also think that Fergusson is probably correct and that the Brahmaputra must have contributed to the building up of North

Bengal even in the olden days and not only since its last diversion through the Jamuna which occurred only comparatively recently. We are starting a contour survey of North Bengal shortly and when the maps with the levels noted therein are ready it might be possible to obtain evidence on a scientific basis in support of this theory. I shall explain later in the course of these lectures how country cross-sections in deltaic area provide indisputable evidence as to the positions of abandoned river courses, their width when active, etc., etc.

Lastly, since the main volume of the Ganges flood began to flow through the Padma channel early in the 16th century, this latter river also must have been helping in raising the southern portion of North Bengal. This probably explains the existence of the vast depression round about Chalan Bil in Rajshahi and Pabna districts which, it seems to me, defines the boundary as between the land raised from the north by the Teesta river systems when they were active and that from the south by the Ganges.

60. In 1787 there was a very high flood in the Teesta and it diverted through an old abandoned course eastward and joined the Brahmaputra near Bahadurabad. The diversion appears to have been effected suddenly as will be seen from Hunter's Statistical Account of Bengal (Vol. VII, p. 165), as quoted below :—

" In the destructive floods of 1194 B.S. or 1787 A.D., which form an epoch in the history of Rangpur, the stream (Teesta) suddenly forsook its channel and turned its waters into a small branch marking an ancient bed of the same river, running south-east into the Brahmaputra,

and forced its way through the fields and over the country in every direction."

61. Before the diversion Teesta used to discharge her waters through the Purnabhaba (now a tributary of the Mahananda), the Atreyi and the Karatoya which used to fall into the Ganges. The large number of spill and drainage channels which intersect Northern Bengal were, in consequence, allowed to continue their beneficent activities and the area was healthy and prosperous. After the diversion of the Teesta, completely cutting off the head water-supply laden with fertilizing silt from the Himalaya, these channels are gradually deteriorating bringing in their train water-logging due to inadequate drainage and progressive deterioration of the country as regards health and productivity of the soil.

River problem in North Bengal and its solution.

62. I confess we know very little about North Bengal and data are lacking. Steps have, however, been taken to start contour survey and collection of other essential data, and after these are ready, it will be possible to state the problem and indicate the solution more definitely. The problem appears to be that being deprived of the silt-laden spill of the Teesta flood there is a growing deterioration in the drainage system, in public health and productivity of the land. Another cause of deterioration of the drainage system is that due to the lack of pressure of upland water from above, the outfalls of the North Bengal rivers are being gradually choked by silt due to the back rush of the floods in the Ganges and the Jamuna. As mentioned before the vast depression near about Chalan Bil probably defines the boundary between the land raised from the north by the Teesta river system and that raised

from the south by the flood spill of the Ganges and the Jamuna. Since the diversion of the Teesta the former process is no longer in operation but the latter, on the other hand, is increasing in intensity due to higher and higher flood levels in these rivers, tending to reverse the direction of country's drainage. The result is that not only the North Bengal rivers are unable efficiently to dispose of the drainage due to local rainfall, but whenever the Ganges or the Jamuna is in high floods, there is acute distress caused by their flood spill entering the above depression and no relief is possible till after the flood season. The solution lies in the restoration of the old condition as far as possible, that is to say, resuscitation of the river system and diversion through them of a portion of the Teesta flood, which is now not only running to waste into the Brhamaputra but causing extensive flood damages and erosion on either bank of the Jamuna. This will enable the land to recoup its productivity with the help of flushing by silt laden floods and the drainage system will also be maintained in efficient condition with the help of the clear spill water draining into these channels after depositing the silt on the land. Till after the contour survey is ready it is not possible to say if extensive land flushing, which alone can improve the productivity of the soil, will be possible. But, it should at least be possible to effect an improvement in public health by improving the drainage system.

MYMENSINGH DISTRICT

Diversion of the Brahmaputra—cause of

63. *Diversion of the Brahmaputra.*—In Rennel's maps the old Brahmaputra flowing past

Mymensingh into the Mehgna is shown as the main channel, and along the present Jamuna channel, through which the main Brahmaputra flood now flows, is shown as a stream of minor importance, probably the Konai-Jenai, which was presumably a spill channel of the Brahmaputra in those days. It appears that being reinforced by the Teesta flood since its diversion in 1787 the Brahmaputra was no longer able to accommodate its waters in the old Brahmaputra channel flowing eastward past Mymensingh and began to cut out a new channel for the additional water more or less along the Jenai and finally succeeded in developing this channel sufficiently to be able to pass practically its entire flood discharge through the new channel, called the Jamuna, at the expense of the old channel. Unlike the diversion of the Teesta this change did not take place suddenly but extended over several decades as can be judged from the old records. Buchanon Hamilton visited the area in 1810 and remarked that the Brahmaputra " threatened to carry away all the vicinity of Dewangunj and perhaps to force its way through the Konai into the heart of Natore." The subsequent diversion took place at Dewangunj and Buchanon's statement proves that even in 1810, *i.e.*, 23 years after the Teesta had joined the Brahmaputra, the diversion did not take place.

deterioration in Mymensingh district and eastern portion of Dacca district.

64. Major Hirst states in his report on Nadia Rivers, 1915 :—

" Lieutenant T. Fisher was employed upon survey work in Sylhet between 1824 and 1830. In 1824 he was ordered to examine the old course of the Brahmaputra from the Jenai to Daodkandi in Tippera, and report why the former

was drying up. That is, nearly 40 years after the Teesta flood, the old river was found to have deteriorated sufficiently to have caused serious comment and inconvenience, and it is clear from this that the desertion of the old channel was not hasty, but deliberate."

Major Hirst concludes that the diversion in question probably took place in 1830, *i.e.*, 43 years after the diversion of the Teesta.

He attributes this diversion to tectonic activity as he says in the report quoted above :—

" A glance at Plate 5 will show that the long axis of Block IV of the old alluvium (Madhupur Jungle Tract), if extended northwards, would dip under the bed of the old Brahmaputra. It has been stated already that old alluvium dips away from such blocks as No. IV. If Block IV rose, the bed of the old Brahmaputra on the north would rise. This is what I believe happened, with the result that the Brahmaputra was forced slowly into the present Jamuna course, which incidentally lies in the direction of the great fault described in Chapter IV. That fault operated and subsided ; Block IV was raised and its long axis at its northern end, by raising the old Brahmaputra bed, diverted the river to the fault line."

65. This theory has, however, been disputed by the Geological experts Messrs. Hayden and Pascoe in their joint note referred to before and also by Mr. T. H. D. La Touche of the Geological Survey of India in his paper published in the Geological Magazine, Vol. VII, 1910. I quote below relevant extracts from this paper, as it throws light on several important points in connection with the changes in the courses of rivers in

Bengal. The explanation given by Mr. La Touche for the diversion of the old Brahmaputra is practically the same as what an Irrigation Engineer would offer, as I have already explained in the course of my previous lecture on the formation of the delta. I shall also revert to this point later while explaining the diversion of the Ganges :—

" Relics of the Great Ice Age in the Plains of Northern India, by T. H. D. La Touche, Geological Survey of India.

Throughout the valley of the Ganges and its tributaries patches of what is known as the ' older alluvium ' are to be found, rising to a considerable height, often as much as 100 feet, above the present flood-levels. This alluvium is generally to be distinguished from the later river-silts by its colour, which has given the name of Rangamati (coloured earth) to so many villages in Bengal and Assam ; and by its containing quantities of the peculiar nodular form of limestone known as 'kunkur,' the presence of which is in itself a sign that the deposits are of considerable antiquity, for it owes its origin to the slow accretion of particles of carbonate of lime dissolved out of the slightly calcareous sediments by percolating water, and redeposited in the form of nodules as the water evaporates.

One of the most conspicuous instances of this old alluvium is the elevated tract known as the Madhupur jungle, extending to the north of Dacca between the present channel of the Brahmaputra and its old course into the Meghna. The soil of this tract is a stiff red clay, evidently an old river-silt but raised to a height of some 60 to 100 feet above the flood-levels of the rivers on either side. Several other patches occur in the

lower Ganges valley, but as we ascend the river and its tributaries into the United Provinces and Bundelkhand we find that this older alluvium is almost universally distributed, and has a distinctive name, that of 'bhangar,' in contrast with the low-lying 'khardar' or straths along the river-courses, and that it bears every sign of being in a state of rapid erosion; that it belongs in effect to a condition of things that has now passed away, when the rivers probably possessed a much greater volume of water and brought down correspondingly greater quantities of silt.

It is always a source of satisfaction to the geologist, or indeed to any scientific man, when he finds that a theory intended to explain a certain series of facts can be used to clear up difficulties that may surround another series of equally well-ascertained facts. The changes of the courses of the rivers of Lower Bengal have for a long time exercised the minds of surveyors, engineers and geologists and various explanations of them have been put forward, especially of the comparatively sudden desertion by the Brahmaputra of its old channel, which ran to the east of Dacca at the beginning of the last century. This problem was first seriously attacked by Mr. Fergusson fifty years ago, and partly turns on the question of the origin of the elevated tract of ground I have already mentioned, the Madhupur jungle. He attributed it to a special upheaval of that part of the delta which deflected the Brahmaputra into the Meghna and the *jheels* of Sylhet. But we should have to apply the same reasoning to other patches of the older alluvium, and it is difficult to suppose that each of them is due to a special upheaval; moreover, one would think

that an upheaval in that particular place would be more likely to force the Brahmaputra westwards than deflect it to the east. Nor does it account for the fact that the Brahmaputra, now a much larger river than the Ganges, allowed itself to be pushed aside in this way; or that, considering that it brings down very much more silt than the Ganges, it should have done so little towards filling up the Sylhet *jheels*. But a study of the present river courses will, I think, throw some further light on the subject.

The Dihang, which, as is now universally admitted, brings down the waters of the Tsanpo of Tibet into the Brahmaputra, is not, I think, the original main channel of the latter, but was, until quite recent times, a mere tributary. It is only within the last thirty years that it has been proved beyond doubt that the Tsanpo is connected with the Brahmaputra, though Rennel was the first to recognize that it must be so in 1765. Only a few days ago I saw a modern atlas in which the Tsanpo was shown as flowing on eastwards into the Salween. Now it is not at all unlikely that, at the period I have been speaking of, the Tsanpo either flowed westwards, as Burrard and Hayden maintain, and escaped through the Himalaya at some other point, or lost itself in the deserts of Tibet, and that then the Dihang was a mere tributary of the Brahmaputra, but that it has since cut back at its head into the valley of the Tsanpo and 'beheaded' it. If this was so, the Brahmaputra must have been a comparatively small river at that time, and it is not surprising that in its lower course it was pushed aside by the alluvium brought down by the Ganges and its tributaries. Indeed it may be

that the Madhupur jungle is a relic of the old delta face of the Ganges, and that to the east of it, at that time, there was open water, reaching perhaps up to the foot of the Khasi Hills; in this way I would account for the backward state of that part of the delta. But when the Dihang beheaded the Tsanpo, and brought down this enormous accession of water, the Brahmaputra began to assert itself. At first it could do little, for the accumulation of alluvium in its path was too great to be swept away, and it had to be content with its old course into the Meghna; but it had a treacherous ally in the Teesta, which had gradually been sapping the defences of the Ganges. The Teesta, wandering from side to side over the old alluvium south of its exit from the hills, swept it away by degrees, wearing down the face of the country to the west of the Madhupur jungle, and in course of time opened a passage for the spill-water of the Brahmaputra down the Jennai river.

Finally the Teesta, frankly deserting its lawful sovereign, the Ganges, threw itself suddenly (this happened so recently as 1787) into the Brahmaputra. The effect of this was not at first noticeable but it is probable that the extra silt brought down by the Teesta was too much for the Brahmaputra to deal with, hampered as it was already by the damming back of its waters by the Meghna as the latter slowly raised the levels of Sylhet, and that the two allied rivers were compelled to find a new channel. The insignificant Jennai offered the means of escape and its bed was occupied about one hundred years ago.

The struggle that then began between the Brahmaputra and the Ganges is still in progress

and issue was joined so recently almost within the memory of men now living that we cannot suppose that it has yet been fought to a finish, or that developments may not take place that will have far-reaching effects upon the future history of Bengal. The Brahmaputra, being the more powerful river, is not likely to rest content with the advantage it has already gained. Up to the present time, indeed, it has not been able to exert its full strength, for it cannot do so until it has brought the level of the Assam valley to the state in which it would have been, had the valley been originally excavated by a river of the size and power of the present Brahmaputra. As it is much of the force of the river, when in flood, is spent in the low ground flanking its course; but when this has been brought to the true 'regimen,' there is no doubt but that the river will be able to show its real strength with more effect in its lower course. Even in 1838 it had succeeded in damming back the Ganges to such an extent near the confluence that the latter was fordable at several places above Goalundo, and was compelled to seek a new exit to the sea. The Garai, which leaves the Ganges at Kushtia, was enlarged from a mere creek unable to float a vessel drawing more than a foot or two of water, as Rennel found it in 1764, to a broad and deep river, now the principal steamer route from Calcutta to the Upper Ganges. What further developments may take place we cannot predict, but it is possible that their influence may be felt still higher up the Ganges, and may even extend to the Jalangi or the Bhagirathi, and so affect the welfare of Calcutta. The mitigation of any evil effects these changes may have is a

matter for the consideration of engineers. If they become acute, something might be done to assist the Ganges by including the Teesta to return to its old allegiance; but the forces exerted by such vast bodies of moving water are so prodigious that it is unsafe to speculate without a complete knowledge of the facts."

The Problem and its solution.

66. As a result of this diversion the old Brahmaputra began to deteriorate rapidly and its present condition is that even at the top of the flood its discharge hardly exceeds 80,000 cusecs as compared with the discharge of the order of well over 20,00,000 cusecs which now flows down the Jamuna channel; while during the dry season it gets cut off from the main channel and runs practically dry except for a small flow contributed by percolation through the sandy bed at its off-take. In consequence there is growing deterioration in the drainage system, in health and productivity of the soil in the Mymensingh and the eastern portion of the Dacca district, which were originally built up and fertilized by this river. About this river also the Irrigation Department possesses very little information, but the Government have accepted my recommendation and a Division has been formed at Mymensingh to study the problems presented by this and other rivers in Mymensingh and Dacca districts and in Chittagong Division and devise measures for necessary improvement. Restoration of the old conditions of flow will probably be an impossible task but it might be possible to improve the old Brahmaputra and the connected drainage system sufficiently for the purpose of improvement in health and agriculture.

Diversion of the Ganges.—As regards the Ganges it seems to have been an admitted fact hitherto that the Bhagirathi originally constituted the main course of the Ganges till the end of the 15th century when the main channel was diverted along the present Padma channel. But in recent years this view has been challenged by late Sir William Willcocks, who, in a lecture delivered before the Calcutta University in 1930, propounded the rather extraordinary theory that the Bhagirathi and other rivers in Central Bengal were originally really canals excavated by the old Hindu rulers of Bengal for the purposes of overflow irrigation.

Diversion of the Ganges—cause of deterioration in Central Bengal.

Canal theory regarding the origin of the Bhagirathi untenable.

As the challenge has come from a delta Engineer of the reputation of Sir William, it seems necessary to examine this point somewhat in detail.

68. A glance at the map of Bengal will show that the extension of the delta towards the sea is the maximum at its western end, *i.e.*, along the Hooghly estuary and the minimum at its eastern end, *i.e.*, along the Meghna estuary, the present outfall of the Ganges. This is in spite of the fact that the Meghna estuary is also receiving the flood of the Brahmaputra which, since her connection with the Tsanpo of Tibet, is much larger in volume than that of the Ganges. This ought to serve as conclusive evidence in support of the established theory that the main volume of the Ganges flood, which constitutes the main delta builder, has been passing down the Hooghly estuary for a much longer period than along the Meghna estuary as at present, unless it can be proved that there were other delta builders discharging, into the Hooghly and contiguous estuaries to the east, floods even larger in volume than that of the Ganges, Brahmaputra and Meghna

Evidence in support of the established theory that the Bhagirathi was the original course of the Ganges.

combined. Such a river does not exist and could not have possibly existed in the present Geological epoch. Taking the present Geological disposition of watersheds and considering the present meteorological conditions, such a river or rivers could have drained only an average rainfall of about 50 inches from the catchment area of about 25,000 sq. miles, which is roughly the combined catchment areas of the rivers of Western Bengal originating from the Chhota-Nagpur and Sonthal Parganas hills. As compared with this, the Ganges alone drains an average rainfall of 42 inches over a catchment area of about 3,50,000 sq. miles and the Brahmaputra, even before her connection with the Tsanpo of Tibet, had a very large catchment area in the submontane region of Assam with an average rainfall of about 88 inches. According to Sir William Willcocks the south-western portion of Central Bengal was built up by the Damodar. That this theory is not at all tenable will be apparent from the fact that the Damodar has a catchment area of only 7,200 sq. miles with an average rainfall of about 50 inches. Its maximum flood discharge is only 6,50,000 cusecs as compared with 20,00,000 cusecs of the Ganges. Floods of this order, again, occur only at long intervals (1913 and 1935) and are short-lived, not lasting more than 2 or 3 days at a time. The average flood discharge of the Damodar and all the western streams combined will be a mere fraction of that of the Ganges.

69. Among other evidences in support of the established theory the following may be mentioned :—

Religious and traditional evidence.—From the mythological period the Hindus have been

considering the Ganges as sacred and people by thousands have been going on pilgrimage to places on the banks of the Ganges such as Navadwip, Katwa, Tribeni, a few miles above Hooghly town (also called Mukta Beni where the Ganga, Jamuna and Saraswati, which were united at Allahabad, were separated), Kalighat and Ganga Saugor all on the Bhagirathi or the Hooghly below the present offtake from the Ganges. No such sanctity attaches to the Padma below the Bhagirathi offtake nor is there any place of pilgrimage on her banks. (*N.B.*—Major Hirst has dealt with this matter more fully in his report "Nadia Rivers, 1915.").

Historical evidence.—Pliny (116 A.D.) and Ptolemy (140 A.D.) mention Tribeni referred to above. Arrian (161 A.D.) refers to Katadupa or Katwa. (Notes by Mr. Reaks published with the report on the Hooghly river and its head waters.) No such places of antiquity are found on the banks of the Padma.

I am also informed by my brother Dr. R. C. Majumdar, formerly of Dacca University, that there is indisputable historical evidence—for instance, the Khalimpur Copper Plate of King Dharmapala (780-820 A.D.)—to show that the Ganges, even above Rajmahal, was also called the Bhagirathi in the olden days. The Padma has never been called by this name; but the western branch is still called the Bhagirathi, thus establishing the point that the latter was really the main course of the Ganges and that the Padma (if it was really in existence then) was either unconnected with that river in the olden days or was a branch not large enough to claim the honour of bearing the same name with the main river.

70. It is also a matter of history that Gaur on the Bhagirathi was the capital of Bengal till towards the beginning of the 16th century, and I quote the following from Major Hirst's report on " Nadia Rivers, 1915 " to show that Padma could not have existed in those days as a branch of the Ganges, or even if it did exist, it must have been a comparatively minor channel, as otherwise both the upper and lower reaches separated by the Padma could not have been named as the Bhagirathi as we find it up to the present day :—

" The upper Bhagirathi (Gaur arm) meets the Ganges and the Padma at the place where the Ganges loses its name. The lower Bhagirathi (upper Hooghly) emanates from the present Ganges on the south bank practically opposite the mouth of the upper Bhagirathi. The alignment of the upper and lower Bhagirathi streams is essentially one which a river would follow and the only portion of the alignment that is missing is occupied by the main bed of the Ganges. From this fact it is clear that if the upper Bhagirathi was the main Ganges originally, and the history of Gaur proves that point, then the Padma as a main river is a more recent channel than the Bhagirathi upper and lower."

Major Hirst's explanation for major changes in the river courses.

71. Major Hirst further reports that " There was a severe earthquake in 1515 A.D. and shortly after it, the Ganges left its old course past Gaur and retreated southwards. The cause of this great change is not known, but it may have been due to earth movements between the old alluvium of Malda and Chhota-Nagpur outliers." In fact Major Hirst attributes the major changes of the river courses in Bengal to tectonic activity which theory has not, however, been accepted by

the Geological experts (Messrs. Hayden and Pascoe of the Geological Survey of India, *vide* Report on the Hooghly River and its Head waters, 1919).

72. But it does not seem to be necessary to rely on Tectonic activity to find an explanation for the changes in the courses of rivers in deltaic Bengal which seem to be not only inherent in their very nature but necessary for the purpose of building and raising of the delta as I have already explained in the course of my lecture on the formation of the delta. Simpler explanation offered.

In the process of building up the delta the river has a tendency to oscillate within wide limits; first flowing in one side and after the riparian tracts have been raised to a certain extent, bursting through its banks and opening up a new channel through the comparatively lower areas of the contiguous tract and so on. After these latter areas have been raised sufficiently, the process is reversed to raise still higher the tract which has been raised before. This is perfectly consistent with the natural condition governing the flow of a river which, following the immutable laws of Nature, always tends to take the line of least resistance. The lower land not only gives it better hydraulic slope but by providing better facilities for spill and consequently abstracting a large portion of its silt burden, helps to maintain the river in a more efficient condition than if it has to pass through higher land.

73. It seems to me that before the diversion of the main volume of the Ganges flood through the Padma channel eastward there were two major river systems functioning more or less independently in building and raising the deltaic tract in this part of Bengal west of Madhupur Reconstruction of the history of the changes.

jungle, *viz.*, the Ganges system operating mainly in Central Bengal and the Teesta system operating in North Bengal. At an earlier stage the latter was reinforced by the waters of the Mahananda and the Koshi, and at a still earlier stage perhaps also by the Brahmaputra before her travel eastward to the Meghna when (*i.e.*, before its connection with the Tsanpo of Tibet) it was, of course, a much smaller stream than it is now. These North Bengal rivers had a combined outfall into the sea, probably through the Meghna estuary. Rennel's map, which was, of course, prepared several centuries after the diversion of the Ganges when the Padma channel was definitely established, shows this combined outfall as Hoorsagor river meeting the Padma or the present Ganges above Goalundo, a little to the north of the present confluence of the Jamuna and the Ganges. Another branch, in a direct line with the above combined outfall, is shown as flowing past Dacca into the Meghna more or less along the present Dhalleswari-Buriganga channel. This latter river was probably the lower section of the combined outfall of the North Bengal rivers in the olden days. Padma or Padmavati was probably in existence then and might have been in existence even from the beginning, constituting the easternmost branch of the Ganges and flowing more or less along the course as shown by Rennel, *i.e.*, following the course of the Bhubaneswar or the Arial Khan as the lower portion is now called. It might also have had a connection with the combined outfall of the North Bengal rivers as shown in Rennell's map.

74. In fact, the existence of this connection makes it easier to reconcile the scientific, historical,

and religious evidences in support of the contention that the Bhagirathi originally constituted the main channel of the Ganges as I have explained before. The outfall of the North Bengal rivers, carrying as it did the combined flood discharge of the Teesta system, the Mahananda and the Koshi, proved in those days to be a formidable obstacle in the way of the development of the Padma. Specially as the Teesta catchment is visited by the monsoon earlier, the Padmavati, when bringing her share of the flood from the Ganges, probably used to find the lower reaches of her channels already occupied by that of the North Bengal rivers. This is a very common phenomenon to be observed in the case of deltaic rivers flowing with a very flat gradient, and a similar struggle has been observed to be going on as between the Ganges and the Brahmaputra since the latter's diversion through the Jamuna channel. Mr. La Touche, in the paper quoted before, observed, "Even in 1838 it (the Brahmaputra or the Jamuna) had succeeded in damming back the Ganges to such an extent near the confluence that the latter was fordable at several places above Goalundo and was compelled to seek for a new outlet to the sea. The Gorai, which leaves the Ganges at Kushtia, was enlarged from a mere creek unable to float a vessel drawing more than a foot or two of water, as Rennell found it in 1764, to a broad and deep river, now the principal steamer route from Calcutta to the upper Ganges."

75. Gradually, however, the Koshi and then the Mahananda threw off their allegience to the North Bengal river system and established direct connection with the Ganges higher up. Not only did this considerably weaken the combined outfall

of the North Bengal rivers but it also reinforced the Padma which could then assert herself in her struggle with the former with greater strength. Lastly, the shifting of the Ganges course near Gaur referred to by Major Hirst, by bringing the Padma more in a direct line of flow, placed her in a more favourable position for drawing the Ganges flood, and as the natural tendency was also in her favour—the building of the western portion of the delta having been more advanced than the eastern portion—she began to develop rapidly at the expense of the Bhagirathi and the other western branches.

76. I hope this explanation will finally settle this question, as it can also be reconciled with the mythological story which is given by Sir William Willcocks in the following words in paragraph 9 of his lecture " Ancient System of Irrigation in Bengal " :—

" The *Mahabharata* tells us that as Bhagirath followed by Ganga descended the Ganges valley, near the head of the Delta, Bhagirath rested to eat his meal ; and Ganga, hearing the sound of Padmavati's shell, thought it was Bhagirath's and followed her in her eastern course down the Padma. It was then that Bhagirath sounded his shell and Ganga recognised her mistake. She retraced her steps and went southwards."

77. Divested of the allegory it means that the Padmavati has been in existence since the ancient time, and the statement "she retraced her steps and went southwards " can only mean that the Padmavati could not develop in her eastward course owing to some obstacles and consequently it was then only a minor branch as compared with the southward channel or the Bhagirathi.

This is exactly what would follow from the explanations that I have given above.

78. Before I conclude this portion of my lecture dealing with the major changes in the courses of the rivers, I might as well refer to another important change that occurred in the lower reaches of the Ganges since Rennell's time. Even in Rennell's time the Ganges did not meet the Meghna about 20 miles above Chandpur as she does now, but she used to flow more or less parallel to the Meghna practically right up to the sea-face where she bifurcated, one branch falling into the Meghna estuary and the other, probably the more important one, had an independent outlet into the sea through the Tentulia estuary flowing to the west of the Dakshin Sabhazpur island. This perhaps gives an explanation for the fact, apparently difficult to explain, that Munshigunj Sub-Division in the Dacca District lying on the north bank of the present Ganges, as also a portion of Madaripur Sub-Division now lying on the opposite bank up to the Arial Khan (lower reach of the Ganges in Rennell's time), though separated by this mighty river, are still called Bikrampur. It will be clear from the above that when the country was divided into Parganas, probably in Akbar's time, these areas were not separated by the Ganges as they are now but formed one compact block lying between the Padma and the combined outfall of the North Bengal rivers.

79. The cross connection between the Ganges as shown in Rennell's map and the Meghna which divided the Bikrampur Pargana into two parts and caused the changes referred to above developed since Rennell's time (about 1870) and was

given the name of "Kirtinasha" because it destroyed the palaces and temples, etc., built by Maharaja Rajballav who was a prominent nobleman of Bengal and was also the Deputy Governor at Dacca near about the time of the Battle of Plassey. Incidentally it may be mentioned that the poet Nabin Sen has written a beautiful poem on the subject. It may be mentioned that there has been considerable change since then and the Ganges has shifted further north and now meets the Meghna about 20 miles above Chandpur. In fact this area can very well be described as the playground of rivers and I have myself observed some important changes since my student days. The Madaripur town, which now stands on the Arial Khan about 2 miles below the outfall of the Kumar at Charmaguria and which is being abandoned owing to vigorous erosion which has already cut away more than half of the town, used to be on the right bank of the Kumar which used to fall into the Arial Khan about 2 miles below Madaripur about 40 years ago. After crossing the Arial Khan we used to go to Palong, Japsa, etc., by a tiny channel called Angaria Khal barely 100 ft. wide. This later developed into a big river called Palong Nalla two to three thousand feet wide and remained the Main Steamer Route to the Ganges for many years. It has now been deteriorating for several years past and is no longer navigable even by light draft steamers in the dry season and will probably again shrink back to the size of the tiny Angaria Khal which I saw when I was a boy. One may naturally ask, "Why this apparent waste of energy? Is it because Nature cannot work with precision or there is a purpose behind all these apparently

inexplicable changes. Prolonged research by means of models may perhaps give the answer one day. Till then an Engineer can only make surmises based on experience, as owing to interaction of mighty indeterminable forces no rational explanation is really possible in the case of many of these changes.

CENTRAL BENGAL

80. There is no doubt but that Central Bengal has been built up by the silt carried by the Ganges which, in the olden days, used to distribute her waters mainly through the Bhairab and the Bhagirathi which, in the lower reaches, trifurcated into three branches at Tribeni a few miles above Hooghly, *viz.*, the Jamuna, the Bhagirathi (or Hooghly) and the Saraswati. Since the diversion of the Ganges flood through the Padma channel, these rivers began to deteriorate. The Bhagirathi, which once constituted the main channel of the Ganges, now remains practically cut off from this river except during floods and even then the share of the Ganges flood it now receives is almost insignificant as compared with what used to pass before the diversion. In consequence, its western and eastern branches, *viz.*, the Saraswati and the Jamuna, are now dead and the Bhagirathi also would probably have shared the same fate but for the rivers in Western Bengal which have their outfalls into this river, and tidal flushing in the lower reaches, which, thanks to the conservancy measures of the Calcutta Port Trust, is being allowed as freely as is possible. But in the upper reaches, the river is fast deteriorating and

Central Bengal—built up and fertilized by the Ganges before her diversion.

After the diversion of the Ganges, the spill channels deteriorated.

even in the lower reaches its condition is not free from anxiety as further deterioration will threaten the very existence of Calcutta as a Port. The Bhairab also is now dead, having been cut through first by the Jalangi and then by the Mathabhanga. These latter rivers opened up comparatively recently after the diversion of the Ganges but they are also fast deteriorating (partly due to artificial interference) and though not completely dead yet, can no longer draw sufficient water from the Ganges to be able to spill over the land or to keep their distributaries alive. The large number of distributary channels such as the Nabaganga, Chitra, Kobadak, Betna, Kodla, etc., which used to distribute this spill over the entire area have also died or are dying, resulting not only in the progressive impoverishment of the soil but acute difficulty in drainage and waterlogging. Practically the whole area traversed by these channels is highly malarious and owing to the lack of sweet water supply in the dry season from above, the salt water limit in their tidal reaches is extending higher and higher up the delta. In fact, the increased salinity of the water of the Hooghly river on which the city of Calcutta is dependent for its water supply is already causing serious concern to the Corporation of Calcutta. It may be mentioned here that the West Bengal rivers contribute very little supply of fresh water to the Hooghly during the dry season, and as their connections with the Ganges also remain cut off then, the only source of supply of sweet water for these spill channels in Central Bengal, which serve an extensive area enclosed between the Hooghly-Bhagirathi, the Ganges and the Gorai-

Progressive deterioration in the productivity of the soil and in public health.

Increased salinity.

Attai series and extending right up to the sea-face, is what they can draw by percolation from the Ganges through the sandy beds at their off-takes and the subsoil storage. This is indeed a serious position and unless a proper solution can be found, this area will gradually revert to swamps and jungles from which it was reclaimed by the rivers.

Restoration of the Ganges spill--the only solution. Its technical feasibility considered.

81. The principal spill channels, which are not yet completely dead and on which we have to depend for the purpose of drawing from the Ganges and carrying a portion of her flood for flushing this area, are the Bhagirathi, the Jalangi and the Mathabhanga. In view of the apparent tendency of Nature to enrich the Padma at the expense of these rivers, the question of primary importance to be considered in connection with their improvement is whether an appreciable portion of the Ganges flood can at all be induced to pass through them in preference to the Padma, of which the hydraulic conditions are of course much more efficient. The late Sir William Wilcox advocated the construction of a barrage across the Ganges with a view to inducing a portion of the Ganges flood to pass through these channels. But the cost of the barrage, together with that of the bank protective works that would be necessary to prevent outflanking and their maintenance, would be so heavy that those who have to finance the scheme may not be disposed to seriously discuss it in the present economic condition of Bengal. We have, therefore, to consider the question of improvement of these rivers even without the barrage.

Ganges Barrage.

82. It may first be considered whether Nature has permanently forsaken this tract or its deser-

tion by the Ganges flood is only a temporary phase. In view of the characteristics of deltaic rivers as explained above, it seems reasonable to expect that after the Ganges has raised the tract through which she is now flowing she will again turn her attention to Central Bengal and the present decadent rivers of these parts may improve. It may be mentioned here that an authoritative committee recently examined the question of head waters of the Hooghly, and after examining all the evidence on the subject, the committee stressed the importance of the Ganges freshets carried by the Nadia rivers (the Bhagirathi, the Jalangi and the Mathabanga) and came to the conclusion that these rivers pass through successive phases of deterioration and improvement and that there is no definite proof that they have permanently deteriorated to any great extent. (Report on the Hooghly River and its Head waters.)

Barrage effect of the Brahmaputra flood.

83. In this connection it may be mentioned that diversion of the Brahmaputra through the present Jamuna channel, which meets the Ganges just above Goalundo, might have given some of these Nadia rivers (at least the Mathabhanga which is nearest to the junction) a chance of revival. The Brahmaputra flood usually reaches the junction earlier and acts more or less as a barrage trying to hold up the Ganges flood which tends to seek some other outlet higher up. But

Development of the Gorai.

unfortunately for the Nadia rivers, such an outlet was found in the Gorai which, in Rennell's time, was only a minor channel but which has since considerably developed. As there is an extensive area of low land yet to raise, the Gorai will probably continue to develop. In fact, even apart

from raising and fertilizing extensive areas of low land along her left bank in the district of Faridpur, thanks to the Halifax cut made by the District Board of Jessore in 1901-02 connecting the Madhumati (lower reach of the Gorai) and the Nabaganga, the Madhumati is now discharging the delta, building functions, left unfinished by the Bhairab and the minor spill channels Nabaganga, Chitra, etc., in the eastern portions of Jessore and Khulna districts. It is, however, possible that after these lower areas have been raised, the barrage effect caused by the Brahmaputra flood may even reach the neighbourhood of the Mathabhanga off-take and a larger portion of Ganges flood might be induced to flow down that channel.

84. The popular view is that the Hardinge Bridge, which was completed in 1915, might also help in improving the Mathabhanga. But the off-take of the Mathabhanga being located about 25 miles higher up the Ganges it does not appear that the bridge has caused sufficient afflux yet to effect any material improvement of the Mathabhanga.

Afflux created by the Hardinge Bridge not material so far.

About half the width of the Ganges underneath the bridge has, however, silted up well above the low water level along the left bank. (*N.B.*—In his inspection report for 1937-38 Mr. K. B. Lal Mathur, Senior Government Inspector for Railways, states that the main stream is round piers Nos. 2 to 6. Piers 7 and 8 are in shallow waters and high *chars* have formed round piers 9 to 16. The maximum velocity during flood is reported to be 14 ft. and the dry season velocity about 1 ft.) As widening of the channel along right or southern bank is being prevented by

But it may increase to be advantage of the Mathabhanga and may even induce far-reaching changes in the regime of the Ganges.

expensive bank protective works and as deepening by scour is being restricted by extensive stone dumping round the piers, it seems possible that this bridge will act more and more as a barrage, with larger and larger afflux, holding up the Ganges flood to seek an outlet higher up. If the afflux increases materially it seems, however, to be more likely that the river will find this outlet in the Lalpur bight, a few miles above Sara on the left bank, and there will be an avulsion through the extensive low areas near about Chalan *Bil*, out-flanking the Hardinge Bridge on the north. But till this catastrophe occurs, the effect of the increase in the aflux, if any, will probably be to improve the Mathabanga.

Mathabhanga off-take appears to be improving.

85. We may have to wait for decades or perhaps centuries before Nature turns her attention to Central Bengal and the point for consideration is whether it is not possible to effect any lasting improvement of these rivers by artificial action. Railway authorities should also be interested in this matter; for diversion of an appreciable portion of the Ganges flood through the Nadia rivers ought to relieve the pressure on the Hardinge Bridge, thus reducing the cost of its maintenance and averting a possible danger of avulsion on the left bank as discussed above. The recent changes in the Ganges which might be attributable to the causes referred to above seem to be hopeful. The huge *char* which hitherto masked the off-take of the Mathabhanga has practically disappeared and its position in relation to the Ganges is definitely improving. The off-takes of the other two principal spill channels in Central Bengal, *viz.*, the Jalangi and the Bhagirathi are also showing signs of improvement

though not to the same extent as in the case of the Mathabhanga.

86. But mere improvement of the off-takes is not enough; it merely shows the tendency of Nature. To be able to utilise fully these tendencies to our advantage, it is necessary to improve the carrying capacities of these channels and provide suitable outlets of distributary channels of adequate capacity, and other facilities for spill over the country-side. For, unless the increased discharge that could be drawn in view of the favourable position of the off-takes could be carried by these channels and disposed of, no material improvement over the present condition can be expected. The function allotted by Nature to these spill channels in deltaic Bengal is that they should spill over the land during floods and deposit the highly fertilizing silt carried by the flood water. Being relieved of the silt burden, the comparatively clear water should then flow down these channels and maintain them in efficient condition. If not allowed to spill, a good portion of the silt content of flood water entering these channels, which the reduced velocity due to flatter gradient available in the lower portion of Bengal is unable to transport, will naturally deposit in their beds, and the channels will again deteriorate. Improvement by dredging or by hand cut where feasible, will no doubt be necessary initially to give these works of improvement a good start. But it is impossible to maintain a river by dredging alone, for, apart from the question of cost, the dredged spoil has necessarily to be deposited on the banks close to the river channels, which will go on rising as the dredging continues and soon reach

Land flushing essential for the preservation of spill channels.

Dredging alone cannot maintain a channel permanently.

a height beyond the lift of the dredger. An essential condition of success, therefore, is that, after their initial improvement, forces which were in operation before, when these channels were in live condition, should be restored so that they may again be self-maintaining or, in other words, they should be allowed to spill extensively over their banks without hindrance as far as possible. To what extent this may be feasible, it is not possible to say without a contour survey with lines of levels taken at fairly close intervals, and detailed investigation made as regards the vested interests that are likely to be adversely affected, and remedial measures to be adopted to safeguard those interests. The problem is undoubtedly a very complicated one and what I wish to emphasize is that no piece-meal solution is really possible but it has to be thought out and dealt with comprehensively.

Introduction of substitute crops for the lower areas of Central Bengal seems to be an essential preliminary to flood flushing scheme.

87. But about one point there seems to be no doubt, *viz.*, the necessity for a substitute crop in the lower areas which would not be adversely affected by uncontrolled flushing when the Ganges is in floods in August and September. In the case of these lower areas also, mostly *bils* and *baors*, the problem to be solved is one of premature reclamation. But since the vested interests have already been created and now constitute the source of livelihood of a large number of people, we have to face the problem as it stands and find a solution. The only practicable solution appears to be that raiyats should be encouraged to grow in these *bils* and other lower areas a crop which can be harvested before the Ganges rises sufficiently high early in August, or the long stem paddy of East Bengal which

grows with the rise in water level and will not be damaged by uncontrolled flushing. In any case, unless a practicable solution can be found for this problem, the prospect of a flood flushing scheme for Central Bengal, which appears to be urgently necessary to arrest the growing deterioration in the health and productivity of the soil as also to revive the dying spill channels, seems to be rather gloomy. It does not appear to be feasible to have controlled flushing without a barrage across the Ganges, the cost of which will, of course, be prohibitive. But even if the flushing could be controlled, in the process of flushing the higher land, the *bils* and other low areas are likely to be inundated to a depth which will probably make it impossible to continue the present method of cultivation. We had practical experience of this difficulty during the recent high floods when, owing to the abnormally high flood level of the Ganges and of its spill channels, crop over a large area of Central Bengal was damaged. Necessity for growing in these low areas a suitable substitute crop, as an essential preliminary step before launching a flood flushing scheme, cannot, therefore, be exaggerated.

History of decadence of Central Bengal and the lessons to be learnt from the frequent high flood in the Ganges—introduction of substitute crops to suit the changing flood conditions appears to the the obvious remedy.

88. Even independently of the flushing scheme, introduction of a suitable substitute crop for these low areas appears to be an urgent necessity, in view of the recent high floods in the Ganges. I have made a critical study of the Ganges flood problem in my paper " Ganges Floods and its Lessons, " from which I quote the following to explain the point :—

" Being deserted by the Ganges the spill channels in Central Bengal began to deteriorate and could no longer flush the country with

the Ganges spill except in years of high floods. The agricultural practices which must have been similar to what we find in Eastern Bengal today had to be changed to suit the changed conditions. Owing to lower and lower level of the floods that occasionally occurred the people gave up the practice of building their houses on high mounds and even the old mounds gradually deteriorated for want of maintenance which was not found necessary. As the flooding became more and more rare owing to progressive deterioration of the spill channels, people began prematurely to reclaim the low areas, mostly *Bils* and *Baors*, by means of embankments, thus cutting off the spill areas of these channels and causing their further deterioration. The process continued until we find today that whenever there is a high flood in the Ganges and these spill channels bring in some flow sufficient to spill over the land, the people suffer not only in the shape of damage to crops which are not suitable for these flood conditions but also by the collapse of houses which are no longer built on high mounds. It must, however, be pointed out that these sufferings are more acute in lower areas which have been prematurely reclaimed before the land could be raised sufficiently high and are partly attributable to the utter inadequacy of the present drainage arrangement as explained above. In fact, having no suitable exit, the flood water simply stagnates over the land to a much higher level than if it could flow into an efficient drainage system.

"The obvious remedy, therefore, lies in reverting to the old practices, *i.e.*, the practices that are now followed in Eastern Bengal as far as it is practicable under the present conditions. To re-introduce the old agricultural practices in the higher land it will be necessary to ensure annual flushing by resuscitating the spill channels. But as regards lower lands it should be possible to revert to the old practices even under the present conditions, that is to say, houses should be built on mounds and long staple East Bengal paddy should be grown, and if that is not found suitable, experiment should be made to find some other substitute crop which will grow in these low areas under the present conditions. These are the lessons we learn from these frequent floods."

89. Before concluding this portion of my lecture on Central Bengal I might mention that a comprehensive contour survey of the decadent tract in Central Bengal has been taken up and will soon be completed. A special division has also been formed recently to investigate and prepare a comprehensive scheme for flushing the decadent tract by resuscitating the moribund spill channels and diverting through them a substantial portion of the Ganges flood. The objects aimed at are as follows :—

Comprehensive scheme under investigation.

(*a*) To arrest the growing deterioration in health and productivity of the soil and restore the old prosperity of Central Bengal.

(*b*) To lower the level of the destructive flood in the Ganges so as to make it harmless and beneficial.

(c) To improve the drainage channels, including the tidal reaches, and make them self-maintaining.

(d) To arrest the advance of salt water limit up the delta.

Steps have also been taken to depute a special Agricultural Officer to investigate into the question of introducing a substitute crop in the lower areas.

Need for the early establishment of the Ganges River Commission.

90. I should, however, make it clear that it will hardly be possible to achieve these objects unless the inter-provincial aspect of the Ganges River Problem already referred to, which is tending to raise flood level and diminish the dry weather flow, can be seriously tackled. To ensure success, both the inter-provincial and provincial aspects of the problem should be attacked simultaneously. In fact, having regard to the delay that will inevitably occur before the effect of any measure in the inter-provincial sphere can materialise, the Ganges River Commission, which alone can initiate such measures, must be established without delay.

Rivers of Group II

Western Bengal

Rivers constitute the only source of supply for irrigation and flood-flushing, which are the pressing needs for Western Bengal.

91. As I have mentioned before while classifying the rivers in Bengal the values of the Western Bengal rivers such as the Damodar, the Ajoy, the More, the Cossye, etc., lie in the fact that they constitute the only sources of supply available for artificial irrigation and for flood flushing. The necessity for irrigation of the *khariff* crops is confined practically to Western Bengal.

Though the total rainfall in Western Bengal is sufficient in normal years, its distribution during the crop period is erratic, specially after the middle of September when rainfall is hardly sufficient to meet the requirement of paddy crops. Even in normal years artificial irrigation is thus a necessity in Western Bengal to ensure a normal harvest. It is a vital necessity in years of abnormally low rainfall—which occurs, say, once in 5 to 7 years—to provide an insurance against famine. Again, since practically the whole of the rural population lives on agriculture and the allied industries and the raiyats are too poor to afford artificial manure, canal irrigation, by providing natural manure in the shape of highly fertilizing silt carried by the canal water, seems to be the only means available for increasing the yield from the land and improving the economic condition of the people.

Erratic distribution of rainfall.

Irrigation—the only means of improving the economic condition of the people.

I do not propose to lengthen my lecture by dealing with this important factor for Rural Development in Western Bengal in details, as this aspect of the problem and its solution are more or less similar to what is experienced in the rest of India. I shall merely emphasise some of the points that have come to my knowledge in the course of my official duties and then pass on to other aspects of the river problems which are peculiar to Bengal.

92. Bengal has an important advantage over the rest of India in the fact that during transplantation season when a very large quantity of water is required by the crops, the rainfall is adequate. In fact in normal years artificial irrigation is usually required to meet the deficiencies of north-eastern monsoon, from the middle of September to the end of October. Unfortunately,

Necessity for storage to supplement the widely fluctuating river flow.

owing to the proximity of their catchment areas to the areas to be irrigated and to more or less similar distribution of rainfall, this is the very time when the rivers in Western Bengal also bring in a rather scanty flow, though earlier in the season, *i.e.*, during the south-western monsoon, they usually bring in enormous volumes of floods which now run to waste. Again, owing to this rather erratic distribution of the river flow the cost of diversion and cross drainage works, which have to be made to suit the maximum flood discharge, is usually rather high, out of all proportion with the comparatively small area that could be irrigated by the dwindling flow in September and October which really determines the irrigable capacity of a stream without storage. It is, therefore, apparent that to meet the irrigation needs of Western Bengal storage is a necessity, *i.e.*, the water should be stored in natural storage works constructed in the upper valleys of these torrential rivers in Western Bengal during floods and utilised in times of scarcity. Storage works are no doubt costly, but as stored water has to be supplied mainly in October when the requirement of crops is the minimum, they are likely to be rather profitable undertakings in Bengal. The area that could be irrigated by a stream by its daily flow can be increased many times over if only a portion of its flood could be stored and utilised in times of scarcity to supplement the daily flow. In Madras where storage works are also needed for transplantation of paddy owing to the failure of south-western monsoon, 1 million cubic feet of stored water can irrigate only about 5 acres. In Bengal, on the other hand, for reasons mentioned before, it can irrigate over 30 acres. Again, for

growing sugarcane and *rabi* crops storage works seem to be an absolute necessity, as from November till April no rain is usually expected in Western Bengal.

93. But though storage schemes seem to be an absolute necessity for development of irrigation and economic uplift of the people in Western Bengal, owing to the flatness of the country it is difficult to obtain suitable sites for storage dams within the boundaries of the Province. For good sites we have really to search in the upper valleys of these rivers lying within the hilly regions of Chhota Nagpur and Santhal Parganas in the Province of Bihar. Two good sites have, however, been discovered so far in connection with the investigation of Dwarkeswar and More projects and it is found that by constructing suitable storage works, etc., about 2,00,000 acres can be irrigated by the former and 4,32,000 acres by the latter.

More and Dwarkeswar Reservoir Projects.

94. The eastern portion of Western Bengal is deltaic, and thanks to human interference with the beneficent activities of these rivers traversing this portion, they have given rise to problems which are unique in the extreme and it is doubtful if a satisfactory solution can at all be found. The area is flat and has been built up by the silt carried by these rivers of Western Bengal, particularly the Cossye in Midnapur district, the Damodar and the Ajoy in Burdwan district. But before the land could be sufficiently raised by such natural deposits, it began to be reclaimed by flood embankments long before the British occupation. In those days, these embankments do not appear to have been efficiently maintained by the zemindars and breaches were frequent.

Unique problems presented by the embanked rivers in Western Bengal.

Though this caused temporary inconvenience and damage to the people, the land used to be flushed occasionally by silt-laden floods and the health and the productivity of the soil did not deteriorate to the extent as it has done now. Evil effects of these embankments were not, of course, realised in those days and for efficient maintenance they were gradually taken over by Government and improved with the object of preventing breaches as far as possible. In consequence, though the breaches are now less frequent and the protection enjoyed by the people is now more thorough, this very fact has brought into prominence the evil effects of these embankments. The breaches are now rare, and even when they occur, they are closed immediately. In consequence the land has been deprived of even the occasional flushing with silt-laden flood water, which it was enjoying when these embankments were being inefficiently maintained by the zemindars. This is not only causing progressive deterioration in the health and productivity of the soil, but being deprived of their source of sustenance, *viz.*, the river spill, the natural channels within the embanked area have all badly deteriorated and the difficulty of draining these areas is becoming more and more acute.

Premature reclamation by embankments responsible for present deterioration.

95. The embankments have not only prevented the gradual rise of the land by silt deposits during flood flushing but, on the other hand, it is actually becoming gradually lower, though at a very slow rate, due to the loss of the surface soil washed away by the rains. To make the case worse the floods, confined within embankments and unable to spill and deposit on the land as was intended by Nature, are depositing a por-

tion of the silt-contents within the river beds which are gradually rising. The Irrigation Engineers in Bengal are thus faced with the most unenviable situation created by the lowering of land to be drained and rise of the river beds into which the drainage has ultimately to be disposed of, and in some area it has already become impossible to drain by gravity. And a very serious situation is developing by the attempt to confine the floods within the narrow channels by means of earthen embankments. As a direct consequence of embanking these rivers, preventing free spill over the country-side, there was a considerable rise in the flood level soon after these embankments were constructed, and this level is tending to rise higher and higher owing to the gradual rise of the river beds, necessitating higher and higher embankments to prevent their being overtopped by the floods. Indeed, during the Damodar floods of 1935 it was observed that, though the embankment was over 20 feet higher than the country level at some places, it was about to be overtopped, which could be prevented only by raising the embankment during the progress of the flood. It is needless to say that breaches at such places would have been attended with serious consequences to the country-side owing to the terrific velocity which a wall of water over 20 feet high, ejecting out of the breach, would have generated, sweeping away everything that would come in its way—houses, cattle and even human beings.

Drainage difficulty gradually increasing.

Rise of flood level necessitating higher and higher embankments.

Sudden and concentrated discharge through breaches much more harmful than gradual inundation.

96. This potential danger to life and property that is likely to be caused by concentrated discharge through breaches at low places needs special mention, and it is here, where high embankments have necessarily to be maintained,

Occasional breaches in earthen embankments can hardly be avoided.

that breaches are more likely to occur. In fact, there is a limit as regards depth of water which can safely be withheld by unprotected earthen *bunds*, and at some places in the Damodar Embankment, this limit has almost been reached and, if the flood level rises higher, it will probably be necessary to go in for expensive surface protection of these embankments. But even then these earthen *bunds* can hardly be made breach-proof, for a tiny little rat-hole may easily lead to a disaster and where there are hundreds of miles of such embankments to look after, it is almost impossible to ensure that all these tiny holes have been detected and attended to in proper time. In fact, such holes are usually covered by vegetation and can only be detected when the flood level has reached their riverside ends, and if these ends are located high up the slope, they may not be detected till the flood has risen very high, when it may be too late to do anything. In view of these difficulties, occasional breaches in the unprotected earthen embankments and the consequent loss of life and property caused by concentrated discharge can hardly be avoided and it is surprising that they do not occur oftener than is the case at present.

Gradual inundation in Eastern Bengal not harmful but a blessing.

97. On the other hand, what would have happened if these rivers were left in their natural condition ? Conditions now prevailing in Eastern Bengal would furnish the answer. No doubt there would have been flooding of the area now inefficiently protected by the embankment, but the flood being allowed to spill over the countryside, the depth of flooding would have been much less and it would be lower and lower as the land rose higher and higher by the silt deposit. And

what I wish to emphasize, there would have been no loss of life or property which is now caused by the high velocity of concentrated discharge through breaches, nor need there have been any distress among the people, for, being accustomed to annual flooding, they would have erected their houses on mounds above the flood level, as is the practice in Eastern Bengal.

98. The position is undoubtedly very serious and unless a bold policy of improvement is followed this tract will, in course of time, revert to swamps and jungles from which it was prematurely reclaimed in the olden days. The ideal solution would be to remove the cause of deterioration, *i.e.*, the embankments, and raise the land and increase its productivity by allowing the flood water to spill and deposit the silt which is very rich manure. Where possible, this solution should certainly be adopted. Millions of tons of this valuable silt is now being carried away by the floods and lost to the country and the land, for which this silt was intended by Nature, is starving. Above the tidal limits where the water is sweet, such natural flood flushing need not necessarily destroy crops nor cause such acute distress amongst the people as is now being caused occasionally by the concentrated discharge through breaches in embankment, for, when the embankments are removed, the flood level will also fall considerably lower, as compared with its present level, and as the floods in these parts are short-lived, lasting not more than 2 or 3 days at a time, such flooding may even be beneficial to the crops except in years of very high floods when, no doubt, the crops will be destroyed till these lands have been sufficiently raised by the silt deposit. The

Bold policy is needed.

The ideal solution.

Land is starving while its source of sustenance is being carried into the sea by the river floods.

loss, however, will be more than compensated by the increased yield in normal years due to the manurial value of silt and improvement in health. And as regards distress caused to the people by the collapse of houses, it can certainly be avoided or at least minimised by erecting houses on earthen mounds and by avoiding mud walls, as is the practice in Eastern Bengal.

Important vested interests come in the way of the ideal solution and controlled flood-flushing seems to be the only praticable solution in most of the cases.

99. In most of the areas, however, owing to important vested interests such as existence of railways, towns, etc., such uncontrolled flood flushing is hardly practicable, and here we must be satisfied with limited flushing as may be found possible by drawing the flood water through regulated escapes to be built on these embankments. It is quite possible to introduce such limited flushing in the area lying between the Cossye, the Selye and the Rupnarain river in Midnapur district and that lying between the Damodar, the Banka and the Hooghly river in Burdwan, Hooghly and Howrah districts. For this latter area considerable progress has already been made towards the proposal for a flood flushing scheme. A contour survey of the area was made a few years ago and being advised that such a scheme was technically feasible, Government appointed a special officer to prepare an approximate estimate of cost. This estimate has since been prepared and it was found during scrutiny that a mere flood flushing scheme, without provision to ensure irrigation in October when rain and river supply both fail in these parts, though highly beneficial as regards improvement in sanitation and productivity of the soil, cannot ensure a good harvest except in years of well distributed rainfall and as such is not likely to be popular nor financially

Damodar-Hooghly flushing and irrigation scheme.

sound. Necessary orders were accordingly isssued to make such provisions, *i.e.*, a storage reservoir in the upper valleys of the Damodar river and a barrage across the Damodar near Burdwan. A detailed project estimate, amounting to Rs. 2,59,92,000, has since been prepared on the above lines, *i.e.*, with provision for a storage reservoir and a barrage to flush and irrigate an area of about 4,27,000 acres in Burdwan, Hooghly and Howrah districts and is now under consideration of Government. The area proposed to be served by the project used to be one of the healthiest and most prosperous in Bengal, and though it has deteriorated to its present deplorable condition mainly by the acts of man, it is hoped that by human acts again it will be possible to retrieve the situation and to restore the area to its original condition of health and plenty.

Need for the rigorous enforcement of preventive measures.

100. It may be mentioned here that as soon as the evil effects of the embankments were realised, the Bengal Embankment Act was passed, in which there is an important provision making it a criminal offence to construct embankments without previous permission within certain areas which are being declared as prohibited from time to time. The area is, however, vast and enforcement of this provision, which involves frequent detailed inspection of the country-side and prosecution of the offenders, is proving to be rather a heavy burden with the very inadequate staff at our disposal.

Increasing difficulty in the maintenance of the Damodar in its present channel.

101. Even apart from flood flushing, so necessary in the interest of health and productivity of the soil, the question of maintenance of these rivers is presenting problems of a more and more serious nature as the years are rolling

by. Considering the Damodar as a representative of this group of torrential rivers, it may be mentioned that in its present condition this river near about Burdwan is barely sufficient to carry more than say 2,50,000 cusecs which represents its normal flood discharge. This capacity is again being progressively reduced, due to gradual rise of the bed in consequence of the marginal embankments, and in the lower reaches, owing to a large quantity of silt brought in by the tides twice daily throughout the year which the occasional floods during the rains cannot clear, it can hardly carry more than say 50,000 cusecs. The potential danger of a flood of the order of 6,50,000 cusecs as occurred in 1913 and 1935 rushing down this channel can now be easily imagined.

Abandonment of the right embankment alone has not solved the problem.

102. Originally the river was embanked on both sides but appreciating this potential danger the right embankment was abandoned towards the middle of the last century. This no doubt relieved the pressure on the left embankment for a time. But the right bank is also gradually rising by silt deposit with more and more pressure thrown against the left embankment and the time is not far distant when it will be impossible to maintain the left embankment unless, either Nature finds a remedy by cutting through the exposed right bank an escape into the Rupnarain, or it is provided by an artificial cut at a heavy cost. In fact, Nature appears to have already cut an escape in the *Begua khal* which is now carrying a considerable volume of the Damodar flood into the Rupnarain, but it takes off too far down the river and about 35 miles of the left embankment protecting a thickly populated area, including the town of Burdwan, and East Indian

Railway line, which runs very close to this portion of the embankment, is still being exposed to the full pressure of the Damodar flood, which is bound to increase more and more as the right bank and the river bed continue to rise by silt deposit.

103. If there were no flood embankments on either side as was intended by Nature, the gain in elevation of the bank by silt deposit would have at least kept pace with the rise in river bed, as has been experienced in the case of the Nile. It appears that the Nile was embanked only recently and that before then "during the Christian era while the matter deposited by the overflow of the Nile has raised the surface of Egypt by 4½ inches per century, the bed of the river has also been raised at the same rate" (Samuelson in his "Note on the Irrawadi River" quoted in Mr. Reak's report on Nadia Rivers). If both the embankments were retained, the country level on both the banks would have remained the same and though an avulsion would have been inevitable ultimately owing to the gradual rise of river bed and consequently of flood level, it would have been left to Nature to cut it either through the left bank towards the Hooghly or through the right bank towards the Rupnarain, probably the latter (as is evidenced by the natural formation of the *Begua* escape) owing to open country available on that side as compared with the left where the country is full of obstructions such as East Indian Railway and Grand Trunk Road Embankments, etc. The policy of abandonment of the right embankment and retention of the left, on the other hand, has resulted in the rapid rise of the country level on the right side and

that on the left side has probably been even lowered by surface washing caused by the local rainfall. The inevitable consequence, therefore, it seems to me, will be that Nature will try to force an avulsion through the left bank towards the Hooghly unless we can take adequate remedial measures in the mean time.

Avulsion through the left bank towards the Hooghly probable.

Potential danger to Calcutta and the large business interests on the Hooghly.

104. Such an avulsion will, of course, mean a serious disaster, for, apart from the very large vested interests on the left bank which will be adversely affected, the important city of Calcutta and the large business interests on either bank of the Hooghly will be in great danger. It is no doubt true that till the middle of the 18th century one of the Damodar outfalls was at Noaserai, a few miles above Hooghly town, but owing to desertion by the Damodar floods since then and by subsequent encroachments, the Hooghly channel has considerably shrunk and near about Calcutta it can hardly carry more than 3,66,000 (Mr. Reak's estimate of maximum flood in 1918) or say 3,50,000 cusecs in its present condition. Seriousness of the situation that will arise by the avulsion referred to above can, therefore, be easily imagined if it is remembered that in 1913 and in 1935 the flood discharge of the Damodar was of the order of 6½ lakh cusecs. And when the Damodar is in high floods, it is very likely that the other western tributaries of the Bhagirathi also will be in high floods simultaneously owing to the proximity of their catchment areas.

Escape through left bank not practicable.

105. The above consideration should rule out any proposal for remedial measure by means of uncontrolled escapes on the left bank, and as regards controlled escapes, it may be mentioned

that the rough estimate which was recently prepared for flushing the decadent area on the left bank referred to before amounted to about Rs. 2 crores. The proposal provided for extraction from the Damodar and its distribution over the area, of only about 13,000 cusecs out of the total maximum flood discharge of about 6,50,000 cusecs, a mere drop which will not cause any material lowering of the flood level nor of its pressure against the left embankment. To afford such relief we should extract something of the order of say about 2,00,000 cusecs. Apart from the prohibitive cost, this extra discharge cannot possibly be carried by the Hooghly in the vicinity of Calcutta and above. Increasing the capacity of the Damodar channel by dredging does not also appear to be a feasible alternative. As I have mentioned before, apart from the question of cost, no river can be permanently maintained by dredging. This is all the more true in the case of the Damodar with such a wide range of flood discharge—maximum flood occurring at long intervals—and with the lower reaches liable to be choked up by silt carried by the tides functioning twice daily.

Maintenance by dredging impossible.

106. As regards remedial measures the only feasible alternatives, therefore, seem to be either to construct flood moderating reservoirs in the upper valleys, probably the most satisfactory though costly solution or to provide an escape into the Rupnarain, through the right bank which should take off from a point as far above Burdwan as is possible. But an escape, unless provided with a channel of adequate capacity to lead the flood water into the Rupnarain, would be merely transferring the complaints from one

The only feasible alternatives—flood moderating reservoirs—are probably the most permanent though the costliest solution.

area to the other. Even then it can hardly be considered to be a permanent remedy, as the channel is likely to be silted up, specially as its outfall into the Rupnarain will be open to the silt-laden tides, which the intermittent pressure of floods from above—high floods occurring at long intervals—will not be able to keep clear. It seems to me that once upon a time the Rupnarain probably constituted the outfall of the Damodar. The tendency of Nature to restore the old condition through the *Begua* escape is not sufficiently helpful. We should help Nature by taking off this escape from a point higher up the river. Along with the escape it is also necessary to improve the carrying capacity of the Rupnarain in her upper reaches by removal of some of the circuit embankments on her banks (Chetua and Mohankhally circuits, etc.), which, for reasons explained before, seems to be necessary even in the interests of the areas prematurely reclaimed by these embankments.

Capacity of the Rupnarain to be increased by the removal of circuit embankments.

Group III

Tidal Rivers

Tidal channels are valuable assets for communication and drainage.

107. In their lower reaches these channels of Groups I and II, discussed above, are tidal and, except where free tidal flushing of their spill areas has been interfered with by premature reclamation, their condition is not so bad and they are still continuing their beneficent activities mentioned above including the provision of cheap means of transport by water, a natural asset, which should be preserved at all cost. Mere tidal flow, unless reinforced by a supply of upland

water, cannot, however, maintain any channel for an indefinite period. Tides in these parts carry a large proportion of silt with which Nature is trying to raise the lower portion of the delta now deserted by the Ganges floods. But it is only a question of time when the spill areas having been raised up to tide level, this silt, unable to spread over the land, will deposit in the channel bed in a larger and larger quantity and will finally choke it. A gutter channel will probably remain for draining the local rainfall but the channels will no longer be fit for navigation. Besides, with the reduction of pressure of sweet water from above, the salt water limit is also being pushed up these channels and a serious situation is likely to arise if the upper reaches of these channels continue to deteriorate and the supply of sweet water is further reduced. In fact, it appears that salinity of the Hooghly water near Calcutta, on which this big city is dependent for its water-supply, is showing a tendency to increase during the dry season. The case is probably similar or perhaps worse with regard to the tidal portion of the other spill channels in Central Bengal, as the only source of sweet water for these channels is the Ganges and from December till June they remain entirely cut off from this source except the very small supply that is drawn by percolation through the sandy bed at their offtakes.

Salt water limit is advancing up the delta.

108. But where free tidal flushing has been interfered with by premature reclamation of spill areas by means of marginal embankments, the situation has already become serious at several places by the deterioration of the tidal channels and the difficulties of drainage are becoming more and more acute. As mentioned before,

apart from serving as carriers of country drainage with which we are all familiar, these rivers of Bengal, both upland flood carriers and the tidal channels, perform the most important function of raising the delta we live in. As owing to the diversion of the Ganges the upland flood carriers are no longer functioning in Central Bengal, tidal channels are the only agencies now left by which the lower portion of Bengal could be raised and made fit for human habitation.

Tidal channels—the only natural agency now left by which the lower portion of the delta could be raised.

Another point to be noted is that when the upland flood carrier dies in a particular area, as for instance in Central Bengal, though that area suffers, its beneficent activities are not lost to the country; only, these are transferred elsewhere. If, however, a tidal channel is obstructed, it usually gets choked in its own bed without any chance of diversion by avulsion as the energy required for the purpose is lacking, it being not possible for a tidal channel to rise above the tide level. Thus the consequence of premature reclamation by marginal embankments or other obstructions in tidal channels is that their beneficent activities of raising this portion of the delta will be lost to the country for ever and the land will continue to remain low, with increasing difficulties of drainage until it becomes unfit for human habitation and reverts to swamps and jungles. We have instances of this almost next door to Calcutta, *viz.*, the low areas served by the Bidyadhari which, owing to earlier reclamation of the spill areas, is now completely dead and can no longer serve as a carrier of drainage, with serious consequences to the city of Calcutta and suburban areas. The Peali is also fast dying and will probably share the same fate as that of the Bidyadhari unless

Death of a tidal channel is permanent loss to the country.

steps are immediately taken to throw open sufficient spill area for this river.

109. In fact, provision of spill areas by removal of marginal embankment seems to be an urgent necessity for prolonging the life of these tidal channels. But this is not enough. If these channels have to be given a permanent lease of life, the supply of upland water seems to be an essential requirement. As this point is not usually understood, it seems necessary to explain the physical characteristics of tidal rivers.

Supply of upland water essential for preservation of tidal channels permanently.

110. The energy which creates the tidal flow, *viz.*, attraction of the sun and the moon in the deep sea, is very limited and is mainfested partly as potential energy, *i.e.*, rise in tide level, and partly as kinetic energy, *i.e.*, velocity of flow. The former causes the tidal flow up the rivers and the latter determines its power of transporting silt. As the velocity of tide, when it enters the mouths of these tidal rivers, is high and as there is a vast reservoir of unconsolidated silt in suspension along the delta face, the tide, as it flows up these rivers, is highly charged with silt. It is generally observed that the duration of ebb tide in a tidal river is much longer than that of the flow tide. As the same quantity of water must ebb out as flowed in, it, therefore, follows that the average velocity of " ebb " is less than that of the " flow ". Now the capcaity of water to transport silt depends on its velocity. It, therefore, follows that the ebb tide is generally unable to transport back fully the silt that has been carried up these tidal rivers by the " flow tide". Even a slight deposition of silt will go on accumulating, as the tides function twice daily throughout the year and the channel

Physical characteristics of tidal rivers.

will begin to deteriorate. The deterioration would impede the propagation of tidal wave which would cause further deterioration, and the vicious circle would continue till the channel is completely dead.

111. It will appear from the above that to maintain the life of a tidal river, what is necessary is an additional supply of water not saturated with silt, *i.e.*, which has reserve capacity to pick up more silt, to supplement the tidal flow during ebb so as to scour out fully the silt that has been admitted into the river by the flood tide. This could be effected either by the supply of upland water, or by local drainage, or by throwing the existing spill area open to the daily ebb and flow, or by adding new spill areas, if possible. The spill area is, of course, an important flushing agent but it would function only for a limited period, at a gradually diminishing rate, till the whole area is raised to high tide level and its storage capacity is reduced to nil. The local drainage would also be very helpful, specially when crops are standing on the fields, as the water would be practically silt-free. But this agent can function only during the rains and for 7 months (November to May) no material contribution can be expected from local drainage, however large the drainage area may be, to help in the flushing of the river during ebb. The third agent, *viz.*, upland water, is certainly the most important, and, if it were possible to arrange for its supply perennially, so as to flush the river even during the dry season, there is no reason why a tidal river should not live and continue her beneficent activities for ever.

112. Improvement of the spill channels of Central Bengal and diversion through them of a portion of the Ganges flood thus appear to be necessary even in the interest of the tidal portion of Central Bengal, as this water, after spilling over the land and depositing the silt content, will have to pass through these tidal channels for disposal into the sea. With the help of a copious supply of sweet water, it will be possible not only to maintain these tidal channels permanently but also to push down the salt water limit and extend cultivation more and more towards the sea-face even without embankments as is the practice in Eastern Bengal. As I mentioned before while lecturing on the Inter-Provincial aspect of our River Problems, forces are, however, at work tending to diminish the dry weather flow of the Ganges which is so vitally necessary for the preservation of these tidal channels in Central Bengal. Mere improvement of the spill channels will not, therefore, be sufficient unless these forces or the harmful acts of man within the catchment basin can be controlled by an Inter-Provincial organization such as the Ganges River Commission as I have suggested.

Restoration of the Ganges spill by the improvement of the spill channels in Central Bengal essential even for the preservation of her tidal channels and to push down the salt water limit.

Need for the early establishment of the Ganges River Commission to conserve the dry weather flow so essential for the preservation of tidal channels in Central Bengal.

113. In recent years the Bidyadhari river has been very much in the public eye owing to the increasing difficulty that is being experienced in disposing of the drainage from Calcutta through this outfall. I, therefore, propose to take up this river as a typical representative of this group and briefly review its life history to illustrate the points discussed above.

Bidyadhari River.

114. As mentioned before while dealing with the primary delta builders of Group I, before

A spill channel of the Jamuna and carried her

share of the upland flood when the Jamuna was active.

the diversion of the Ganges flood through the Padma, the Jamuna constituted one of the main branches of the Ganges taking off at Tribeni through which this flood used to flow down to the sea. In fact, between the Bhairab and its branches to the east and the Hooghly river to the west, the Jamuna was perhaps the most important delta builder in those days and largely contributed to the raising of this portion of the Sunderbans. The Bidyadhari was an important spill channel of the Jamuna and to her was allotted the task of raising the delta just to the east of the areas near about Calcutta. Channels connecting the Bidyadhari with the Jamuna in the olden days (*Nowi*, *Sunti* and *Nonagong*) can still be traced reaching within a few miles of the present abandoned course of the Jamuna.

Indisputable evidence left by Nature—banks much higher than the tide levels.

115. But the most indisputable evidence that the Bidyadhari used to receive a considerable supply of upland floods is given by the width between high banks of what is now called Bidyadhari *khal* just above Bhangore canal. In fact I was surprised to find such high natural banks in the midst of what was known to be a purely tidal area when I inspected the *khal* in 1933 and had several cross-sections taken to ascertain whether they were really above the high tide level, as that would prove conclusively that the Bidyadhari used to receive upland floods. As the cross-sections show that these banks are much above the high tide level even of the present day (which must be considerably higher than when the river was allowed to spill freely over the banks), they could not have been built up by the tidal silt but must have been raised by the silt carried by the upland water. Having regard to

the characteristics of delta builders of which the banks slope away from the river edge, the width between the crests of these high banks, therefore, gives a rough measure as to the extent of upland flood supply in the olden days, and judged by this standard it must have been considerable.

Width between crests of banks gives a rough measure of her old prosperity.

' *N.B.*—The width varies from 350 ft. to 900 ft. the average being 660 ft., and the level of the bank from 10.21 to 16.66, the average being 12.57 within a length of about 10 miles above Bhangore canal. As compared with this the highest tide level recorded at Bamanghata on the Bidyadhari, which is progressively rising, was 10.33 and average high water 8.8 in 1932. At Haroa (a short distance above the length considered) the H. H. W. and average H. W. level in 1932 were 11.0 and 8.75 respectively.

All levels referred to O. M. S. I. or P. W. D. datum.

116. I would particularly emphasize the importance of this method of reconstruction of the life history of deltaic rivers by means of cross-sections. After completion of the contour survey of Central Bengal, we shall have a lot of data to help us in this direction. For instance, from cross-sections of the country round about the Saraswati I found that this river, which now looks like a gutter, was originally a big river, thus corroborating the view that the Saraswati was a branch of the main Ganges, as there is no other delta builder on this side of the country which could throw off a branch of this size.

Field for research in reconstructing the life-history of rivers in deltaic Bengal.

117. By similar evidence left by Nature it was also found that the Kultigong which now constitutes the outfall of the Nowi, Sunti and Nonagong, formerly feeders of the Bidyadhari,

Kultigong—a later channel.

probably opened up much later than the Bidyadhari. In any case it was originally a channel of minor importance as compared with the Bidyadhari. Measured from the present outfall of the Nonagong into the Haroagong (the connecting channel between the Kulti and the Bidyadhari) high banks much above the high tide level extend only a little over 6 miles along the Kulti route while along the Bidyadhari they extend at least 14 miles. I have discussed these points at length in my official report on the " Bidyadhari Restoration Scheme." The conclusion that I arrived at after a critical analysis of all the available evidences may be summarized as follows.

Life-history of the Bidyadhari river reconstructed.

118. So long as the Jamuna remained active the Bidyadhari used to get a considerable supply of upland water (including a portion of the dry weather flow of the Ganges), not only the flood carried by the Nowi and Sunti but also at least the major portion of the flood carried by the Nonagong. Deterioration of the Jamuna probably set in soon after the diversion of the main volume of the Ganges flood towards the end of the 15th Century or early in the 16th Century. But it seems probable that it still continued to receive, at least during the rains, a share of the Damodar flood which had one of its outfalls into the Hooghly near Kalna till at least 1660 and near Noaserai till about the middle of the 18th Century, both the places being above the offtake of the Jamuna at Tribeni. Diversion of the Damodar down its present channel, with its outfall below Uluberia on the latter date, finally sealed the fate of the Jamuna which together with the spill channels began to deteriorate rapidly.

Stoppage of upland water-supply and meeting of tides—natural causes of deterioration.

119. Deprived of the upland water supply Bidyadhari was then thrown entirely on her other resources, *viz.*, local drainage and spill area, to prolong her life as long as she could. At this stage another characteristic, peculiar to tidal rivers carrying a large proportion of silt, hastened her decay. The Kultigong, the next parallel tidal channel to the east, had already opened up and by means of the connecting channel, now known as the Haroagong, provided a meeting ground for tides coming up both this river and the Bidyadhari. Owing to check in velocity there is always heavy deposition of silt at the tidal meeting ground; but so long as these rivers received a plentiful supply of upland floods, this silt could be cleared by flushing during floods. After stoppage of this supply, this silt, deposited as a result of the meeting of the tides, became a grave menace to the preservation of both the channels. Nature had thus to sacrifice one for the preservation of the other. It seems to me that by this time the Kultigong, which was originally discharging into the Matla through Kumerjolgong, had her present outfall into the Roymangal estuary definitely established. Now the Roymangal is one of the deepest estuaries in the delta and the conditions for the propagation of tidal wave being more favourable, the stronger tide up the Kultigong could travel higher and higher up the connecting channel (Haroagong), thus shifting the tidal meeting ground more and more down the Bidyadhari. The Nonagong, the Sunti and the Nowi, which originally used to feed the Bidyadhari, were thus gradually absorbed by the Kultigong for her own sustenance. By robbing the Bidyadhari of

the drainage and spill areas of these feeders, the Kultigong thus began to develop at the expense of the Bidyadhari and the latter river deteriorated rapidly.

Death of the Bidyadhari hastened by the acts of man.

120. But though the fate of the Bidyadhari as a permanent channel was thus sealed, the existence of large spill area in the salt lakes should have made it possible for her to function as an outfall for the drainage from Calcutta and the neighbouring areas for a much longer period but for the acts of man. The salt lakes, even after reclamation along the borders, now measure about 55 sq. miles and, it seems to me, define the boundary between the area built up from the north by the upland floods and that from the south by the tides carried up the Bidyadhari and the Peali. Even after the stoppage of upland floods it should have been possible for Nature to raise this area by tidal deposit, instead of leaving it as a nuisance so close to the city, but for human interference.

Rise in tide level—an inevitable sign of deterioration.

121. The first interference was the premature reclamation of the land on either bank of the Matla and the Bidyadhari by means of marginal embankments towards the middle of the last century. This was one of the earliest areas to be reclaimed and consequently both the channels began to deteriorate with progressive rise in tidal level or what may be called "heaping up of tides." At Port Canning (Bidyadhari outfall into the Matla) the highest high water level has risen from 6.28 in 1865 to 12.83 in 1930 (O. M. S. L. datum). At Dhappa the ordinary high water level in 1830, as it is gathered from old records, was 1.5 in the dry season and 3.5 in the rains. The high water level was 9.41 in 1926.

At Bamanghata on the Bidyadhari, the highest high water level has risen from 9.1 in 1894 to 11.00 in 1926. It will be of no use referring to the levels at Dhappa and Bamanghata in recent years, as tidal flow is practically non-existent and the level is really ruled by the discharge of Calcutta drainage. It may only be added that the present level is considerably higher and the Bidyadhari, which hitherto used to drain Calcutta, is now trying to drown the city with the sewage and we are trying to prevent the catastrophe by means of flood embankments proposed to be constructed along the eastern boundary.

Significance of "heaping up of tides" explained.

122. Now this "heaping up of tides," which occurs when tidal wave is unable to dissipate itself over spill area, is another characteristic of tidal rivers, and where tides carry a large proportion of silt as in Bengal, it causes deterioration of the channel by the dropping of silt. The explanation is probably as follows: "Heaping up" of tidal flow really means gain in potential energy. But as the sum total of the energy which generates this flow, *viz.*, tidal impulse created in the deep sea by the attraction of the sun and the moon, etc., is constant during each tide, this gain in potential energy must be attended with a corresponding loss in its kinetic energy; or in other words the flood tide can only rise in level at the expense of its velocity. Now the silt carrying capacity of the flow being proportional to its velocity, it follows that as soon as "heaping up" occurs, a portion of the silt brought up by the tides, in excess of what the reduced velocity can carry, drops on the bed, thereby further impeding the tidal wave and accelerating

the deterioration of the channel in a vicious circle. This phenomenon of "heaping up of tides" is going on more or less in almost all the tidal rivers, where spill area has been unduly curtailed and really constitutes the preliminary warning of deterioration. In the Bidyadhari and at the head of the Matla Estuary, the "heaping up of the tides" is probably the worst, as their spill areas have been the earliest to be reclaimed. It is less and less as we move towards the eastern parts of the delta.

123. The second stage of human interference was the discharge of the Calcutta sewage into the Bidyadhari. While the liquid content has probably been helpful, specially during the dry season, the solid matter has certainly been harmful, specially by forming a gelatinous coating over the channel bed and slope which the ebb flow finds it difficult to scour. The large number of fisheries in the salt lakes and other low areas also contributed to the deterioration of the Bidyadhari, by preventing free tidal spill. Finally the Kristopur canal (excavated in 1910), by cutting off a good portion of the salt lake spill area (Ghuni Jatragatchi—about 18 square miles) and interfering with the natural drainage from the north, accelerated the death of the Bidyadhari.

All attempts for revival of the Bidyadhari have failed.

124. Attempts were made to revive the Bidyadhari both by acquiring spill area (about 2½ sqare miles, which was found to be rather much too small) and also by dredging at a heavy cost. But opposing forces were found to be much too strong and the Bidyadhari continued to deteriorate. She is now absolutely dead without any chance of revival and it would be

interesting to note the rapid rate of deterioration from the following figures :—

	1883	1904	1936
Lowest Bed level— near Bamanghata referred to O. M. S. L. or P. W. D. datum	−58.69	−29.71	+5.75

N.B.—Present bed is even higher than the country level on either side.

	1894	1915	1917	1926	1932	1936
L. L. water level at Bamanghata	−4.9	0.0	+0.17	+2.5	+5.92	+11.05

	1926	1936
Cross sectional area at Bamanghata below R. L. 9.75	2,440 sq. ft.	363 sq. ft.

Life of the Peali River must be prolonged in the interest of the drainage of a large area.

125. All attempts at the resuscitation of the Bidyadhari have now been rightly abandoned and the Calcutta Corporation are dredging an independent outfall into the Kultigong. As the proposal has received the approval of Government and the work is in progress, I refrain from making any comments. Nor would such comments be really appropriate on this occasion, as I am only dealing with the river problems in general and am not aiming at finding a solution to any specific local problem like the drainage problem near about Calcutta, which is sufficiently important and complex to form the subject of a special paper. I wish only to add in this connection that the Peali, a branch of the Bidyadhari, is also fast deteriorating and will soon share the

same fate as the Bidyadhari. Immediate steps are, therefore, necessary to prolong the life of this river. After the death of the Bidyadhari, the Peali is now the only channel left to dispose of drainage from a large portion of 24-Parganas district and constitutes the outfall of several drainage schemes constructed by Government at heavy cost. The death of the Peali will not only mean loss of this capital but, due to consequent water-logging, the area affected will gradually revert to swamps and jungles from which it was prematurely reclaimed by the acts of man.

River Problems with reference to Navigation

Waterways constitute a valuable natural asset.

126. I have dealt with the river problems in Bengal so far as they have arisen in respect of the beneficent activities of the rivers in draining and fertilizing the land which they have created. I now refer to another aspect of the river problems in respect of the valuable services which the rivers are rendering to the country in the matter of carrying the produce by cheap water route. Together with the tidal portion of Central Bengal, Eastern Bengal possesses very important natural resources in her navigable channels, the value of which in promoting trade and providing facilities for cheap communication can hardly be exaggerated. We have first the principal highways, *viz.*, the Ganges, the Brahmaputra and the Meghna, providing water communications with the neighbouring provinces of Bihar and Assam. Then we have the networks of feeder channels connecting these main waterways with the trade centres including Calcutta, one of the important

ports in the world. Again, in Eastern Bengal which is inundated by the floods of these rivers, it is possible during the monsoon to carry goods by water practically from every village to the nearest feeder channel and from there to one of the principal highways for transport to the several trade centres. This is perhaps unique in the history of the world, for, though there are other countries possessing natural waterways, I do not know of any, where the system of internal boat communication has been so thoroughly planned by Nature as in these parts. Apart from its value to trade it is also providing employment to hundreds of thousands of people, the importance of which in a province like Bengal, where the pressure of population is already being felt, can hardly be exaggerated.

Need for Inter Provincial organization for conservation of waterways so vital to Bengal

127. The importance of conserving and improving, where possible, this valued gift of Nature is, therefore, obvious. But the problem of their conservancy is mainly Inter-Provincial in character and can only be tackled with the co-operation of the upper Provinces and States by an Inter-Provincial organization like the Ganges River Commission, the constitution of which I have already advocated while dealing with the Inter-Provincial aspect of our River Problems. For purposes of navigation an ideal channel would be one which would carry more or less about the same flow throughout the year and year after year, with silt content limited to what its velocity could transport, so that there may be sufficient depth of water for navigation and formation of shoals may be avoided. Such an ideal channel is not, however, found in Nature, specially, in tropical countries, where the heavy rainfall during

the few monsoon months, followed by dry weather during the rest of the year, requires, for the accommodation of the heavy run-off, a channel many times the size which would be required if the rainfall were more evenly distributed. The size of the channel is, in fact, determined by the volume of normal high floods, and as it often has to carry smaller floods, the velocity drops, leading to the formation of shoals which are the main obstacles to navigation, specially during the dry season when the river level drops by 20 to 25 ft. in our principal highways.

By controlling the catchment basin with a view to increasing the dry weather flow and reducing the silt content of the flood.

128. Apart from these vagaries of Nature over which we can have no control, there are controllable factors in operation created by the harmful acts of man within the catchment basin and in the river channels, as I have already explained, which are accentuating these inequalities in the distribution of flow, tending further to diminish the dry weather flow and to increase the silt content of the flood, leading to the formation of more shoals and greater difficulties in navigation. Indeed, according to local tradition, some of the Western Bengal rivers, which are now classed as torrential and are not navigable even during the rains, used to be navigable for a considerable length inland in the olden age. Constitution of Inter-Provincial River Commissions with sufficient authority and resources to be able to control these harmful acts of man, therefore, appears to me to be an urgent necessity, as otherwise even our principal highways like the Ganges and the Jamuna may cease to be navigable in course of time. This is the most important measure that I could suggest for a solution of our navigation problem which is

already growing rather acute in parts of Bengal.

129. Referring to its Provincial aspect the main problem which we have to face at present in the matter of improving facilities for communication by water is with regard to the feeder channels connecting these principal highways, especially with Calcutta. In the olden days, when the Bhagirathi was in a better condition, Calcutta was, of course, directly connected by water with the Ganges. Later, as navigation through the Bhagirathi became more and more difficult, the Jalangi and the Mathabhanga were being utilized for the purpose. In those days steamers were, of course, unknown and navigation even by boats was difficult during the dry months, as can be gathered from the old records. It appears that even till about the middle of the last century there was considerable activity in connection with attempts made to maintain the Mathabhanga as a feeder route to Calcutta from the Ganges.

Maintenance of the feeder channels consitutes the main navigation problem in the provincial sphere.

N.B.—The Churni, connecting the Mathabhanga with the Hooghly, appears to have been an artificial cut made in the interest of navigation.

Most of the supply drawn from the Ganges by the Mathabhanga offtake was in those days escaping into the Kumar and steps were taken to prevent this by artificial action. It also appears that in 1860 and 1861 five chord cuts were made across some of the bad loops of the Mathabhanga, thereby shortening the river by 21 miles and making its fall equal to that of the Kumar.

130. But these attempts did not prove very successful, and more and more attention was paid in improving the boat route through the Sundar-

bans. Construction of Calcutta canals, including the Chitpur lock, was taken up early in the 19th century and the canal route was gradually improved by the construction of the new cut canal in 1859, Dhappa, Bamanghata and Kulti locks in 1895 and, lastly, the Kristopur canal in 1910. But this canal route was intended for boats. When steamers were introduced later, they used to enter the Bidyadhari through the Tolly's *Nalla* (excavated in 1770) and take the Sundarban route *via* Port Canning and Matla. Owing to the deterioration of the Bidyadhari and the Matla the steamer route is being gradually shifted more and more towards the sea-face. Here again Nature has helped us by providing cross connections between outfalls of the primary delta builders (estuaries), usually flowing north to south. But for these cross connections navigation from Calcutta to the Ganges would have been difficult by steamers and probably impossible by boats, as they would have to pass out into the sea to get into the next north-to-south channel and so on. In fact, our main problem at present in respect of navigable waterways is with regard to the maintenance of these cross connections; though the maintenance of the north-to-south channels is also proving to be more and more difficult and will be impossible ultimately, as these channels, in the absence of upland water supply and with spill areas prematurely reclaimed, continue to deteriorate, as experienced in the case of the Bidyadhari and the Matla.

Cross channels—valuable natural gift.

Origin of cross channels explained.

131. The existence of these cross channels is probably attributable to the funnel shape of the Bay of Bengal, the deepest sea being in the middle ending in the "Swatch of no ground"

more or less in a line with the centre of the delta and shallower and shallower sea running along the coast lines to the east and west. Owing to more favourable conditions available for the propagation of the tidal wave along the deeper or central portion of the Bay, the tide makes first at the head of the " Swatch of no ground " and travels along the delta face, one branch running to the west and another to the east. For this reason as also due to the irregular extension of the delta as pointed out above, the tides do not make absolutely at the same time at different points in the same latitude along the delta face, thus giving rise to cross currents between the deeper channels just below the outfalls of contiguous north-to-south delta builders. As pointed out by Major Hirst (Report on Nadia Rivers, 1915), the delta, in consequence, has not probably extended continuously but in the shape of islands between two contiguous outfalls, leaving a cross channel between the island and the mainland. So long as the difference in the time of arrival of the tide at either end was such as to prevent the formation of tidal meeting ground within the cross channel, it remained. But where, owing to irregular extension of the island at its outer face, due probably to one delta builder being more active than the other, this difference was altered so as to provide tidal meeting ground within the cross channel, it closed up, joining the island with the mainland. In this way many of the cross channels have now disappeared, throwing the steamer route more and more to the sea-face. The gradual rise of the tide level, with tendency to drop a larger and larger proportion of the silt content, has also helped in this process.

Meeting of tides —a grave menace to the maintenance of the cross channels.

132. It has been stated before that along with the improvement of the rivers in Central Bengal in their upper reaches and the diversion through them of a portion of the Ganges flood, their tidal reaches will also automatically improve and with the copious supply of upland water thus available a solution will be found to maintain these tidal channels on a permanent basis, which is so vitally necessary in the interest of inland navigation in Bengal.

Difficulties in the maintenance of the Lower Kumar river—cross connection between the Madhumati and the Ganges.

133. In this connection it may be mentioned that to shorten the distance by water between Calcutta and the Ganges the Madaripur Bil Route was opened early in the present century. As the name indicates, it was a passage about 20 miles long cut through a series of *bils* connecting the Madhumati at Manickdah with the Kumar river at Fatehpur and through that river and the Arial Khan with the Ganges. The scheme was highly successful, as the spill of the Ganges and the Madhumati, after depositing the silt on the *bils* and the countryside lying to the north and west of these channels, was sufficient to give them a thorough flushing and they were more or less self-maintaining. This route practically monopolized the whole volume of waterborne traffic between Calcutta and Behar and Upper Assam and apart from immense benefit to trade, it was also yielding decent revenue to Government. But to meet the demand of the growing heavy traffic it was considered necessary to widen the *bil* route, which, in consequence, began to draw more and more of the available spill supply at the expense of the Kumar, which, for want of sufficient nourishment, is now being starved to death and navigation is no longer

possible during the dry months. It is a highly complicated subject and cannot be properly dealt with in a short note. But I mention it just to indicate that in this case also we have got the requisite natural resources in the large volume of flood water now running to waste in the Ganges and the Madhumati and the problem is one of diverting a portion to feed the Kumar which is starving to death for want of adequate supply.

134. While dealing with this subject of communication, I may be permitted to sound a note of warning, specially to those who live in areas which are still being favoured by Nature in the shape of annual flood flushing. We hear the talk of extension of railways in these parts, for instance railroad to Barisal, to Madaripur and between Dacca and Aricha, etc. Improvements or facilities for communications are certainly necessary, as these are vital factors in the cultural and economic uplift of a nation. But railroads in these parts have to be carried on high embankments, materially interfering with the flushing arrangement devised by Nature. We should not, therefore, repeat the mistakes as made in the case of Western Bengal, and instead of embanked roads or railways, our policy in future should rather be to meet the demand for communication in these parts by improving the existing waterways and making new waterways where none exists at present.

River Problems with reference to Erosion

135. Another problem that I would like to mention before I conclude is what is being created, specially by the primary delta builders of Group I,

Erosion problem —inherent in the condition of flow of deltaic rivers. Research

necessary to find out a satisfactory solution.

in Eastern and Northern Bengal, by rapidly eroding their banks. The problem is to a certain extent inherent in the conditions of flow of deltaic rivers, but it is being aggravated by the controllable factors in operation, created artificially by the acts of man, tending further to increase the intensity of floods, as I have already explained while dealing with the Inter-Provincial aspect or our River Problems and by the natural tendency to concentrate all available flow into the two principal rivers—the Ganges and the Jamuna. Resuscitation of the rivers in Central and Northern Bengal, so as to enable them to carry their due share of flood water, will no doubt make the position somewhat easier but the erosion will still continue to remain a problem, as the soil through which these rivers flow is extremely friable. Special study in a laboratory may perhaps reveal some cheap method of river conservancy by which this problem can be satisfactorily solved. But the method of direct action, *viz.*, protection of the eroding bank by brick mattress, etc., that is now followed, is so very costly that it can hardly be adopted except for the protection of important towns.

Silt factor dominates the river problems in Bengal.

136. It will be seen from the above that the all-important factor which dominates the river problems in Bengal is the large proportion of silt carried by the floods. It is the silt which has created the land and made it habitable by raising it through centuries. It is the silt again which is fertilising the land, and where the process is still operating, the country is healthy and prosperous, and where it has ceased to function, the country is progressively deteriorating in health and productivity of the soil. But though

the silt has proved to be such a beneficial gift of Nature, this very factor has given rise to most of our river problems that we find today. It is the silt which, by deteriorating the old river channels, has forced their diversions through lower areas which, though beneficial to the latter, have been so harmful to the areas served by the former, as we have seen in case of Central and Northern Bengal. It is the silt which, by raising the beds and consequently flood levels of embanked rivers, has created problems highly complex and unique in character, as we have seen in the case of the rivers of Western Bengal, specially the Damodar. It is the silt which has killed many of the tidal rivers in Central Bengal and threatens to kill the rest, with disastrous consequence to the interests of navigation and drainage, unless we can reinforce the ebb flow in its struggle against the silt brought in by the flood tides. It is the silt, again, which is killing the cross channels so valuable in the interests of navigation, which, like a thoughtful mother, Nature left between north-to-south channels for the benefit of Bengal in the process of extending the delta. Silt, in short, is one of our greatest benefactors and, in some respects, also a malefactor, and we ought to make the closest study of this all-important factor. Unfortunately, we possess very little information on the subject beyond the general knowledge as indicated above. What is required is a Research Officer with a fully equipped laboratory to study this and other questions amenable to laboratory treatment, thoroughly and scientifically, to guide us in our effort to solve the rather complicated river problems in Bengal. Many of these problems are

Need for the establishment of a River Research Institute in Bengal.

rather unique without any parallel. Practices followed elsewhere will not, therefore, help us much, but we have to find a solution ourselves by long and concentrated study of the local conditions.